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WAR DEPARTMENT

TECHNICAL MANUAL

LINK TRAINER
OPERATION AND TRAINING

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WAR DEPARTMENT,
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LINK TRAINER, OPERATION AND TRAINING

Prepared under direction of the
Chief of the Air Corps

CHAPTER 1

BASIC COURSE IN TRAINER

SECTION I

OPERATION

1. **General.**—*a.* The aim of this manual is to present a comprehensive text for Link trainer students. However, it is believed its arrangement is suitable for a general reference for pilots.

b. It is impossible to put on paper all the knowledge necessary to be a good instructor. There can be no substitute for individual train-

ing and experience in both the art of instruction and the use of special equipment. It cannot be overemphasized that for maximum results the instructor must be one who thoroughly understands his subject, is able to do the things he is to teach, and has the ability or knack of imparting the knowledge and skill to others.

c. The exercises following are the result of combining the experience and methods of several successful link trainer and instrument flying instructors, both military and commercial, and their practical value has been proved. It should be remembered that this is only a guide or outline and that the alert instructor must supplement and enlarge upon it in order that the ideas and suggestions are entirely clear to a student under the hood. This should be done, however, without deviating too much from the trend of the outline.

2. Unlocking and relocking trainer.—*a*. *Unlocking*.—With the student seated in the trainer, warn him not to turn the switch on or off until asked to do so. While steadying the trainer with the right hand on the handgrip under the tail, release the rear locking strap with the left hand. Holding the trainer in a slightly nose-down position with the right hand, hook the left thumb around the side locking strap. Give the order to "switch on" and as the motor starts release the side strap. Until airspeed is built up above stalling speed the trainer will try to spin. Still holding the tail handgrip, the instructor should steady it until rudder control is attained.

b. *Relocking*.—*Be sure the "rough air" is turned off*. Secure the side strap first while steadying the trainer with the right hand on the stick or wheel. The rear lock may be maneuvered into position by using the longitudinal control in the rear fuselage with the right hand engaging the lock strap with the left. As the strap approaches the locking position, ask for "switch off" in a loud tone as the student probably is still wearing the phones. Swing the trainer around until the door lines up with the step.

3. Use of phone system.—The instructor should bear in mind that nearly all of the student's attention is occupied with trying to keep the instruments reading as they should. It is therefore necessary to speak much more clearly than in ordinary conversation. The rate of speech should be about 25 percent slower than normal and full value given to each syllable. While it is desirable to cultivate a pleasant voice, a monotonous smoothness should be avoided as it will not penetrate the already overtaxed consciousness of the student. The student should be instructed to raise his voice slightly and direct it toward the microphone.

4. Use of beam volume and A and N controls.—When working orientation problems, great care should be taken to insure smooth facing or building up of signal strength. A sudden change is not natural to radio reception and gives information to the student in the wrong manner, especially in fade-out problems. It is equally important that the A and N or beam shift control be given close attention in order to maintain proper continuity of signal from a clear N or A through the twilight to the "on-course." The instructor should watch the position of the inking wheel of the recorder, in relation to the radio station on the map, and move the controls as necessary to make the signals sound right. This cannot be done accurately by setting the controls by sight to any given mark. The instructor should know how the signals sound in actual flight and be able to duplicate them by ear. There are occasions when it is advisable to exaggerate signals. When a beginner in radio flying is drifting off an on-course, it is often difficult for him to recognize the fact immediately and he frequently misinteprets A's for N's. Giving him strong, exaggerated signals at this stage will speed up his progress appreciably. As his perceptions improve, the signals should be gradually made to duplicate the actual radio as he will hear it in the air.

5. Training procedure.—*a.* The instructor should be prepared to hear from most new students in the trainer, "Why, this doesn't fly at all like an airplane." It should be remembered that in instrument flying "feel" must be ignored; that the student must "fly the instruments," hence it is not important that the trainer does not feel like an airplane. Since feel and stability are purposely entirely lacking in the trainer, the student will be forced to learn to fly entirely by instrument. No one has been heard to complain that the turn knob of an automatic pilot does not feel like a rudder. The knob is used to make an instrument read as desired, and the wheel and rudder should be used with the same thought in mind. No attempt should be made to rush a student through in any given number of hours. Perfection should be the only goal. Ability to fly on instruments should be built as a carpenter builds a house; the early stages of instrument flying practice laying a foundation for a structure which will be only as strong as its foundation.

b. To many pilots, some of the maneuvers given in the following exercises may appear elementary and unnecessary, and they will want to skip them and get on to the more interesting radio work. The instructor should not allow this and should never assume knowledge on the part of the student, just as in navigation—radio or other—the student should never assume but prove. The best place for the in-

structor to start being thorough is with the first lesson. The student should be required to prove his understanding of each maneuver by explaining back to the instructor what he is going to do. If the student has previously acquired the ability to execute the apparently simple elementary maneuvers, he will not be delayed long by having to demonstrate his ability. He can progress rapidly until he reaches an exercise he cannot perform satisfactorily. If a weakness in the student's ability is discovered and corrected in these early exercises, he may sometime have occasion to thank his instructor for his thoroughness. And the conscientious instructor will enjoy more peace of mind if he knows his students have covered each phase thoroughly.

SECTION II

EXERCISES

6. The 1-2-3 system of instrument flying.—*a.* The 1-2-3 system applies only to the rate instruments which will be described and refers first of all to the order in which the instruments are to be read, that is—

(1) Turn indicator.

(2) Ball bank indicator.

(3) Airspeed indicator.

The readings of all these instruments can be checked almost at a single glance. It will be found that in straight and level flight in still air the turn indicator, ball bank indicator, and climb indicator will all be centered, and the airspeed indicator will show cruising speed.

b. The 1–2–3 system also refers to the order in which the controls of the airplane are to be operated in order to make a turn, a glide, a climb, or any other maneuvers, or to recover to straight and level flight from any position. The relation between the instruments and the controls may be tabulated as follows:

(1) Turn indicator controlled by the rudder.

(2) Ball bank indicator controlled by the ailerons.

(3) Airspeed indicator controlled by the elevators.

The 1–2–3 system is based upon this association of each instrument with its corresponding control.

c. To maintain or to return to straight and level flight, the application of the 1–2–3 system is as follows:

(1) Center the turn indicator with rudder only.

(2) Center the ball bank indicator with ailerons only.

(3) Control the airspeed indicator with elevators only.

This sequence of operations is very important, but it is equally important to consider that number 1 and number 2 are to be very closely coordinated, and that number 3 is to be carried out almost at the same time. The pilot must bear in mind that the bank indicator should *always* be kept centered or slightly on the high side during a turn, *never* on the low side, either in a turn or in straight flight, to assure the correct lateral position of the airplane.

d. With a full understanding of the cause and effect relations between the controls and the instruments, and with suitable practice in the sequence of operations as outlined above, the pilot should have no difficulty in applying the 1–2–3 system. It will be, in fact, almost as simple as it sounds—"one, two, three."

e. The pilot will soon learn to follow through the 1–2–3 system just as the driver of an automobile in starting or stopping or in turning a corner does several different things each in proper sequence. The pilot will read each instrument and operate the corresponding control, each at the right time, without stopping to think what to do next.

f. The 1–2–3 system has the advantage of being both simple and definite. It definitely associates each instrument with its proper control. It is understandable, easy to remember, and easy to apply, and it applies equally well for any desired maneuver of the airplane.

7. Familiarization with trainer and instruments.—*a*. Have the student take his place in the trainer and explain thoroughly the 1–2–3 system of instrument flying. Point out to him the various instruments and explain their functions and how they are controlled. The student may be a pilot who has hundreds of hours of contact flying, but this does not prove that he knows anything about instrument

flying. Do not assume that he knows anything about it. Remember, he does not know *all* about it or he would not be in your classroom. Since you do not know the points on which he is weak, it is necessary to cover the subject completely. If the student is inclined to say, "Yes, yes, I know all about that," and is impatient to get on, ask him to explain the 1–2–3 method and control of the instruments to you. If he does know, no time need be wasted; but if he has misconceptions as to the proper procedure, you can set him straight so he will not waste even more time later in the course.

b. When the foregoing procedure has been thoroughly covered, unlock the trainer as previously described. Five to ten minutes may be spent with the hood up if the student has never been in a trainer. It is a waste of time for the student to spend a half hour to an hour getting the feel of the machine. Remember that he is starting to learn instrument flying where feel must be ignored not used. Any mechanical tricks the student might learn about the trainer with the hood open will only handicap him later. He will waste time trying to hold the trainer in the proper attitude by means of these tricks and by feel, and will not make real progress on instruments until he has unlearned these shortcuts and finally started to read the instruments. Before placing the student in the trainer, the instructor should turn on the radio in the trainer desk so that it will be warmed up and ready. The student should be asked to put on the earphones and the use of the microphone should be explained to him.

c. After unlocking the trainer, the instructor should immediately take his place at the desk and microphone and continue the instruction from there. Have the student apply a little rudder and note the reaction of the turn indicator needle; ask him to bank in one direction and then the other and observe the ball bank indicator; have him move the nose up and down with the elevators and note the reaction of the airspeed indicator; and have him open and close the throttle and check the reaction on the airspeed, tachometer, and vertical speed indicator. Not more than 10 minutes should be spent during this period with the hood open. The student should then be asked to close the hood. With the hood closed, again ask the student to go through the maneuvers just completed; outlining the process one step at a time, have him note that with the hood down the same controls have the same effect on the instruments that they did with the hood open. When the student has a clear understanding of how the 1–2–3 system at least ought to be done, and demonstrates that he understands what controls affect which instruments, he is ready for exercise number 3.

8. Straight course.—*a.* This exercise is designed to acquaint the student with the number one instrument of instrument flying, the turn (and bank) indicator. During its practice the directional gyro must be caged. Before starting the exercise, no effort should be made to attain any given altitude or in fact any altitude at all. The airspeed indicator likewise receives no attention other than enough coaching to keep the student out of a spin. The problem at this stage is simply to learn to control the turn indicator. A certain amount of attention will, however, have to be given the ball. Explain to the student that if the ball gets off to one side the turn indicator needle will have a very pronounced tendency to get off on the same side also. (Naturally, the ball on one side indicates that a wing is low and that the craft will shortly start turning in that direction just as an airplane does in actual flight. But do not make the mistake of talking too much to the student about the attitude of parts of the craft; rather, confine your comments to the instruments themselves.)

b. Explain thoroughly why it is necessary to average the swings of the turn indicator needle. Point out that if the needle is observed to be off to one side it is definitely essential that it be offset an equal amount, for an estimated equal period of time, on the other side before centering it, in order to return to the desired heading.

c. The student should be frequently cautioned against becoming tense, and should be requested to relax by momentarily letting go of the controls and by moving around in the seat. He should also be warned against becoming hypnotized by any one of the instruments to the point that he can neither relax nor look over the rest of the instrument panel. Tendencies toward tenseness and overconcentration on some one instrument will be found in nearly every student, and the instructor must be constantly on the alert if he would have his students make normal progress. In connection with this it is not advisable to have the student spend more than 30 minutes under the hood at a time.

d. The foregoing straight course exercise should be continued until the student can hold a straight course within + or − 10° over a 5-minute period.

9. Straight and level flight.—*a.* In starting this exercise the student should be requested to open the throttle wide and maintain cruising airspeed. A climb will of course result. The student should maintain the same airspeed and hold the same heading until an altitude of 1,000 feet is reached. When this altitude is reached the student should be instructed to throttle back sufficiently just to hold

the altitude, still maintaining cruising airspeed and holding his heading.

b. Since it is the purpose of the early (and subsequent) exercises to form mental and physical habits in the instinctive or subconscious control of instruments, the instructor must remember to follow the 1–2–3 order in giving commands, especially in getting the student out of difficulties; for example, "Stop the turn with the rudder only; center the ball with the ailerons only; and check the airspeed with the elevators only;" etc. Even if only one instrument has moved away from its desired indication, start at the beginning and go through the 1–2–3 order, emphasizing slightly the instrument in question.

c. As the student throttles back to remain at the assigned 1,000-foot level, he must move the elevator control forward slightly, hold it there for a few seconds, and then return it to neutral in order to prevent the airspeed from decreasing. In the process, the vertical speed indicator should be brought to zero. It is very important that it be drilled into the student to control the vertical speed with the *throttle* only and the airspeed with the *elevators* only; and that he must *not* try to control the vertical speed with the elevators. The airspeed must be held at cruising with the elevators and the trend of the altimeter noted. If altitude is being lost, more power must be applied; if gaining altitude, slightly reduce the power. *A correction must not be applied either to throttle or elevators because of the altimeter or vertical speed indicator without first checking the airspeed.* If there is doubt as to whether the student is following this rule, the vertical speed indicator should be covered until the student has demonstrated his ability to control the airspeed.

d. The majority of students encounter considerable difficulty in controlling the airspeed. The instructor must keep an attentive eye on the trainer and note any tendency of the student to overcontrol and to let the airspeed oscillate. When such difficulty is present (and it usually is), the student should be instructed to make smaller corrections and to allow them time to take effect. The instructor should explain the so-called lag in the airspeed indicator; make clear that the lag is nearly all due to the comparatively slow rate of acceleration and deceleration of the airplane itself; that after a momentary correction has been applied which has slightly changed the attitude of the ship, it will take a few seconds for the craft to pick up or lose enough speed to reflect in the airspeed indicator. For example, if a ship capable of 200 miles per hour were being climbed, full throttle, at 100 miles per hour and the stick suddenly pushed forward enough to put the airplane in a level flight position, it is to be expected that it will

take several seconds for the ship to reach its full speed of 200 miles per hour.

e. Bearing the above in mind it naturally follows that if the stick had been held forward until the airspeed actually reached the 200 mark, the ship would have continued nosing down until by the time the indicator showed the 200 the ship would have been in a steep or vertical dive. It is therefore necessary to remove the correction on the elevators long before the airspeed has reached the desired amount. This is known as "leading" the airspeed indicator. The amount that it must be led will depend upon the speed at the moment and the rate at which the pointer is moving. The faster the pointer is moving the more it must be led. For example, in recovering from a stall or near stall, the correction to the elevators must be removed almost as soon as the airspeed starts to increase, in order that the nose not be allowed to get too low.

f. Since a student's future success as an instrument pilot, and indeed his very life, will depend on his ability to control the turn and bank indicator and the airspeed indicator, it is vitally necessary that the preceding exercise be continued until he has a complete understanding of their control. Minimum standards of proficiency on this exercise should be the ability to hold the heading within + or − 5° for 5 minutes, airspeed constantly within + or − 10 miles per hour of cruising, and altitude definitely within + or − 100 feet. It should be borne in mind that these are minimum standards and neither the student nor the instructor should be satisfied but should strive for better results.

10. Standard rate turns.—*a*. A turn of 180° per minute (3° per second) or a one needle-width deflection, either right or left, on the turn indicator is considered a standard turn. When the command to make a standard turn is given by the instructor, the student should take up this rate. In order to make a smooth standard turn, a great deal of coordination of the controls is necessary in entering, during, and in the recovery to straight and level. The turn should be started by use of the rudder and followed almost simultaneously by the ailerons and then the elevators to keep the airspeed constant. Lead with the rudder, follow with the ailerons as necessary to control the ball, and maintain the airspeed with the elevators. Once the proper turn is set, it is not difficult to maintain a constant rate, but it is necessary constantly to be rechecking the needle, the ball, and the airspeed to keep the correct attitude.

b. In the recovery it is equally important for the controls to be coordinated for a good smooth recovery. By knowing, applying, and practicing the 1-2-3 system this will soon become a very simple

operation. After giving the command for the student to recover to straight and level flight, the instructor should frequently use the following terms and expressions until they become habit to the student: "Stop the turn with the rudder only; center the ball with the ailerons only; check the airspeed elevators only; correct altitude with the throttle only."

c. During the practice of standard rate turns, the student will usually encounter difficulty in holding the turn steady due to the ball getting off center. The chain of events that usually occurs is as follows: the ball will get slightly on the low side (banked too much) causing the turn needle to move too far from center (rate of turn speeded up). The student will correct the needle without proper coordination, and the ball will then be still farther on the low side. The student then usually rolls the ball to center again without proper coordination of the rudder and the turn stops. Stopping and starting the turn in a series of jerks will result. To remedy the trouble, the student must be taught how to "cross controls" when he wishes to correct the ball without disturbing the turn needle, or correct the needle without disturbing the ball.

d. The following subexercise will usually correct the student's difficulty and give him a clear understanding of the trouble; have him hold the turn indicator needle centered and slowly roll the ball to the left just barely outside the lubber lines. Have him note that the turn needle tries to follow the ball and that to keep the needle centered it is necessary to give right rudder. Then have him roll the ball to the right of the lubber lines and note that to keep the turn needle centered he must slowly remove the right rudder previously applied and gradually apply left rudder. After a few minutes spent in this practice, have the student start a standard turn and during the turn roll the ball slowly from side to side as just outlined, meanwhile maintaining the turn needle at the desired mark.

e. In general, during the practice of all turns the ball should be kept just slightly on the high side (not more than 1/16 inch outside the lubber line). The ideal place to maintain the position of the ball is, of course, in the exact center. However, since the student instrument pilot does not have perfect control, and the ball must not be permitted on the low side (because of turn tightening and the resulting diving spiral), he should be definitely required to carry it slightly on the high side.

f. Standard turns of 360°, 270°, 180°, and 90° should be practiced. These turns should be made with the turn indicator and clock, and the instructor should check their accuracy with a stop watch. The

student should not pass on to the next exercise until these turns can be made with not more than 10° of error for each 90° of turn, the airspeed held within + or − 10 miles per hour, and the altitude maintained with + or − 100 feet of that assigned.

11. Standard rate turns to compass headings.—*a.* It is very essential for the student to be thoroughly familiar with the compass rose and to be able to interpret compass headings in degrees very quickly. This knowledge and ability will be indispensable in problems to follow.

b. In making turns to compass headings two things will be practiced, the turn and the use of the compass. The proficiency of the student will be based on his ability to make a smooth turn of the least magnitude to an assigned heading. For instance, if a student flying on a heading of 90° were directed to make a standard turn to the heading of 180°, he would make his turn to the right. If he were to make his turn to the left, he would be covering three times as much distance as the turn to the right would require.

c. These turns should be made by the count without using the clock. If the sweep hand on the clock is not the type which can be stopped it should be covered up. Amounts of turn should range from as little as 10° to as much as 360°. The student should count out loud so the instructor can check and correct his cadence. Trying to count seconds as "one . . . two . . . three," etc., is not usually successful, because whenever the student is diverted momentarily by one of the instruments his cadence will speed up or slow down. It has been found that the cadence can be maintained much more accurately if the space between counts is filled by some convenient word of the right length and rythm; for example, "uh thousand and one uh thousand and two uh thousand and three," etc. The accuracy of cadence can be further increased by counting in units of ten; 1 2 3 4 5 6 7 8 9 10 1 2 3 4 5 6 7 8 9 20 1 2 3 4 5 6 7 8 9 30, etc., still using the "thousand and." To aid in remembering how many units of ten have been counted, the student should raise one finger on the wheel or stick for each unit.

d. The value of this exercise is sometimes questioned by students. The instructor should remember that it has several purposes, only one of which is merely to make turns by the count. For one thing, it is the first exercise which gives the student a little practice in thinking—and remembering—while still controlling the instruments.

e. The directional gyro should be caged and the accuracy of the turns checked by the instructor with a stop watch and the tags on the trainer base. The minimum of proficiency should be an error of

not more than 10° for each 90° of turn, the airspeed held within + or −10 miles per hour, and the altitude within + or −100 feet.

12. Coordination of throttle and elevators (gyro caged).—*a.* Considerable time is usually lost by the student when he attempts climbs and glides because of his lack of ability to coordinate the throttle and elevators; when he tries to correct the vertical speed with the throttle, the airspeed changes; and when he tries to correct the speed, the vertical speed gets out of bounds. Much of this trouble can be smoothed out and time saved later on by the following exercise: starting at cruising speed, have the student slow down to gliding speed, still maintaining his heading and holding a constant altitude. The gyro should be caged and the horizon covered. The process is to lose the airspeed with the elevators and prevent a climb with the trottle. The student should press back slowly on the elevators and at the same time gradually close the throttle partially as necessary to maintain the vertical speed indicator at zero. When the student has the instruments steadied down at gliding speed, have him return to cruising speed. The airspeed must be regained with the elevators, meanwhile opening the throttle as necessary to prevent loss of altitude.

b. The exercise should be continued until the student can perform it smartly, smoothly, and within the following limits: heading within + or −5; altitude within + or −50 feet. During this exercise (as well as several others), if the trainer is not equipped with remote indicating instruments, the instructor will be of much more help to the student if he will obtain and use an extension cord for the desk mike and earphones, and stand outside the peephole in the trainer and watch the instrument reactions.

13. Straight climbs and glides.—Straight climbing and gliding should be practiced at cruising airspeed (at slow speed in a later exercise), and at vertical speeds of 400 and 500 f. p. m. (feet per minute), starting at, say, 1,000 feet altitude, the student should be asked to climb at 500 f. p. m. to a new altitude of 2,000 feet. Upon reaching the assigned altitude the student should level off and maintain that altitude + or −50 feet. Then have him descend at 500 f. p. m. back to 1,000 feet altitude. When a fair degree of proficiency has been acquired, the changes in altitude should be reduced to 500 feet so that the student is given more practice in going into and recovering from climbs and glides, thus obtaining additional practice in throttle and elevator coordination and also to get more repetitions of the exercise into a half hour session. During this exercise the instructor should be particularly on guard against the

student becoming careless with the airspeed, remembering the ever-present temptation on the part of all beginners to attempt to control the vertical speed with the elevators. Minimum proficiency: airspeed + or −10 miles per hour; heading within + or −5; vertical speed within + or −100 feet of desired mark.

14. **Climbs and glides while turning** (gyro caged).—Climb or glide to an altitude predetermined by the instructor. For example, from an altitude of 1,000 feet, do a standard rate (3° per second) climbing turn to an altitude of 2,000 feet at 500 f. p. m. Climbing should be started at the same instant the turn is started, and the turn and climb both smartly stopped on reaching the 2,000-foot mark. If executed correctly the maneuver will be completed in exactly 2 minutes, and the recorder will show that 360° of turn were made. A simple analysis will inform the instructor what errors were made by the student. For example, if the maneuver occupied 2 minutes and 15 seconds and the recorder indicated that 405° of turn were made, it is obvious that the rate of turn was correct (3° per second), but the student has been slow getting the rate of climb to the desired figure or had not held it at the proper indication. In short, if the vertical speed is maintained at the proper indication, the maneuver takes 2 minutes. If the turn indicator is controlled properly, the recorder will show 3° of turn for each second the student spent executing the maneuver.

15. **Climbing and gliding turns to predetermined altitudes and headings** (using clock, gyro caged).—*a.* The following exercise is designed to give the student practice in doing several things at once. It requires him to remember a new heading and how long it will take to reach it and to remember his new assigned altitude; he must stop one maneuver while continuing another (and he cannot be sure which will occur first until the indications are reached); and he must keep close track of several instruments. During each problem the instructor should time each turn and change in altitude with the stop watch.

b. With the student flying level at, say, 1,000 feet, ask him to change altitude to 1,500 feet and at the same time do a right turn of 170°. The climb and the turn must be started simultaneously. When he reaches the new heading the turn must be stopped and that heading held, and he is to level off when he reaches the 1,500-foot altitude. A climbing turn of 200° to the left should then be made, stopping the climb at an altitude of 2,000 feet. If the maneuvers are well-executed in making the 170° turn, the new heading will be reached only a few seconds before the new altitude; in the 200° turn the new altitude will be reached a few seconds before the new heading. If

the exercise is not accurately done the student cannot tell which goal (the new heading or the new altitude) will be reached first, so consequently must keep close track of both the turn and the altimeter as well as the other flight instruments. The exercise should be accomplished within the following limits: airspeed within + or − 10 miles per hour; rate of turn within + or − 10° for each 90° of turn. On reaching the new altitude it should be held within 50 feet and the new heading, when reached, within + or − 5°.

16. Practice in rough air.—Briefly review numbers 7, 8, 9, and 10 with the rough air on. Airspeed limits should be reduced to + or − 5 miles per hour. Other limits remain as before.

17. Slow flight practice.—Repeat numbers 9 and 10 at gliding airspeed (without rough air).

18. Emergency pull-up.—This exercise is one which has a very practical application when the instrument pilot some day gets down to his minimum altitude and finds that he still has not broken out of the overcast, and finds it necessary to go around again or proceed to his alternate station. Require the student to attain an altitude of, say, 2,000 feet and slow flight (gliding) airspeed. Then instruct him as follows: still maintaining a constant airspeed throughout the maneuver, descend at 500 f. p. m. to an altitude of 1,500 feet. Upon reaching this exact altitude ease the throttle fully open and climb back to 2,000 feet. Upon reaching 2,000 feet, level off and hold this altitude, still maintaining slow flight airspeed. When a fair degree of proficiency has been acquired, require the student to start a turn of 45° at the time he reaches the minimum altitude and starts back up. Proficiency: airspeed + or − 5 miles per hour; heading held within 5; vertical speed within + or − 100 feet per minute.

19. Stalls (without spinning).—*a*. This exercise is designed to acquaint the student with the appearance of the instruments at the approach of a stall, and to drill him in instinctively applying the proper correction and leading the instruments back to normal flight indications.

b. Request the student to reduce the airspeed slowly by nosing up. Continue to reduce airspeed gradually and note the action of the vertical speed. In trainers that cruise at 160 m. p. h. with the pointer in the 3 o'clock position, the vertical speed indicator will start to fall back at around 90 m. p. h. In properly adjusted trainers the vertical speed will fall back to the vicinity of zero before the trainer starts to spin. (The instructor should be acquainted with the performance of his particular trainer). The airspeed at which "mush" is indicated on the vertical speed should be noted and the speed then recovered

to normal. Straight flight should be maintained with the turn and bank indicator throughout the maneuver.

c. The exercise should be repeated several times, reducing the airspeed each time until the vertical speed falls almost to the point where a spin will occur. During the exercise the ball should be kept centered and the heading held within + or − 5°.

20. Spins.—*a.* The chief value of the spin in the trainer is to aid in further immunizing the student to vertigo and to drill him in correctly reading and controlling the instruments regardless of any physical sensations he may experience.

b. Spins should be entered smoothly as in an airplane. Do not allow the student to jerk the stick or wheel back suddenly as if he were attempting a snap roll. Rather, require him to reduce the airspeed slowly, noting all the instrument indications as he does so, until the trainer starts to spin. When a spin is started ask the student to apply full rudder in the direction of the spin and to pull the stick or wheel back. The nose of the trainer remains high, of course. The student, however, cannot see the attitude, and if he had never watched anyone else spin the trainer it is doubtful that he would be aware of the nose high position. The instruments indicate properly (for a flat spin, as the airspeed continues to fall back), and since the recovery must be made by instrument the attitude is unimportant.

c. The angular movement possible in the trainer is, of course, limited. Therefore, the trainer will reach a terminal velocity and limit of nose down movement when down against the front stop. In teaching spins in the trainer, it is very important that the student not be permitted to nose down too far and rest against the front stop when recovering. If he is permitted to form such a habit in the trainer, when he attempts recovery from a spin in an airplane, he will push the controls forward too far or hold them forward too long and put the ship on its back. Permitting the student to build up excess speed should be carefully guarded against.

21. Turns to gyro headings.—*a.* Inasmuch as most of the preceding exercises have been performed without using the directional gyro, the student may not be acquainted with the use of the instrument. Practice in setting it to the magnetic heading (making use of the deviation card) and in making turns by it should be fully understood by the student. Be sure the student understands that he cannot obtain an accurate reading from the compass unless the craft is flying straight and level and at a constant airspeed.

b. Standard rate turns should then be practiced, stopping the turns on predetermined, exact gyro headings. The turns should range from

as much as 30° to as little as 5°. For the purpose of this exercise there is no point in wasting time making turns of more than 30°. By keeping the length of the turn short, a much greater amount of practice will be obtained in stopping the turn on specified headings.

c. Practice should be continued until the student can stop the turn and keep it stopped exactly on any specified heading. During the exercise the instructor should time the turns with the stop watch and thus check the accuracy of the student's handling of the turn indicator needle. The airspeed should be held within + or − 5 miles per hour.

22. Use of artificial horizon.—This instrument has been purposely left out of the exercise up to this point to insure that the student is thoroughly trained on the rate group. Intelligently used, however, the horizon is a valuable aid in reducing fatigue and in doing more accurate instrument flying. Its limitations should always be borne in mind and a constant cross check be maintained on the other instruments. Its chief value lies in the fact that as long as it is functioning correctly it has no lag, and indicates the attitude of the airplane relative to the horizontal with practically no need for interpretation on the part of the pilot. This is a very considerable help when making low approaches on instruments to an airport. The airspeed and vertical speed indications can be considerably smoothed out with the aid of the horizon. Require the student to practice changing from cruising speed to slow speed and vice versa by reference chiefly to the horizon. While at cruising speed, have student note the position of the miniature airplane relative to the horizon bar, then have him reduce speed to gliding speed and note the position of the airplane and bar. Having noted the two positions, have him change the attitude so as to put the airplane and bar in their cruising position, maintaining altitude with the throttle as usual, and note that the airspeed returns to cruising. Then nose up until the little airplane and bar are in their position for gliding speed, meanwhile maintaining level flight (constant altitude) with the throttle, and note that the speed smoothly reduces to gliding speed. Practice should continue until the exercise can be executed smartly, meanwhile holding the altitude within + or − 100 feet and the heading within 5°.

23. U-track.—*a.* A signal should be agreed upon so that when the student is ready to start the problem the instructor will start the recorder. As the student signals that he is ready he should start the sweep hand of the clock. This course (north) is held for 1 minute. (See fig. 1.) At the end of this period, the clock should be stopped, cleared, and started over; and at the same time the 90° turn to the right should be started. The turns may be stopped by the gyro, but

the pattern will be spoiled if the turn indicator is not properly controlled throughout the maneuver. The clock should be stopped and started over again at the end of each straight run and each turn.

b. The problem should be started at an altitude of 2,000 feet. After coming out of the first turn onto the east heading, the student should climb to an altitude of 2,500 feet. At the start of the turn from the fourth leg (northbound) onto the west leg, a descent of 500 f. p. m. should be started. Continue the glide to an altitude of 1,500 feet. This altitude should be held throughout the rest of the problem. On the last leg, prior to going into the last turn, the airspeed should be reduced to gliding speed. As the final turn is completed, the student should signal the instructor who will shut off the recorder. The starting point and finishing point should be within 1/8 inch of each other with slow recorder motors. The altitude should be held within + or − 50 feet, except when changing to a different level as previously prescribed and the proper airspeed maintained within + or − 5 miles per hour.

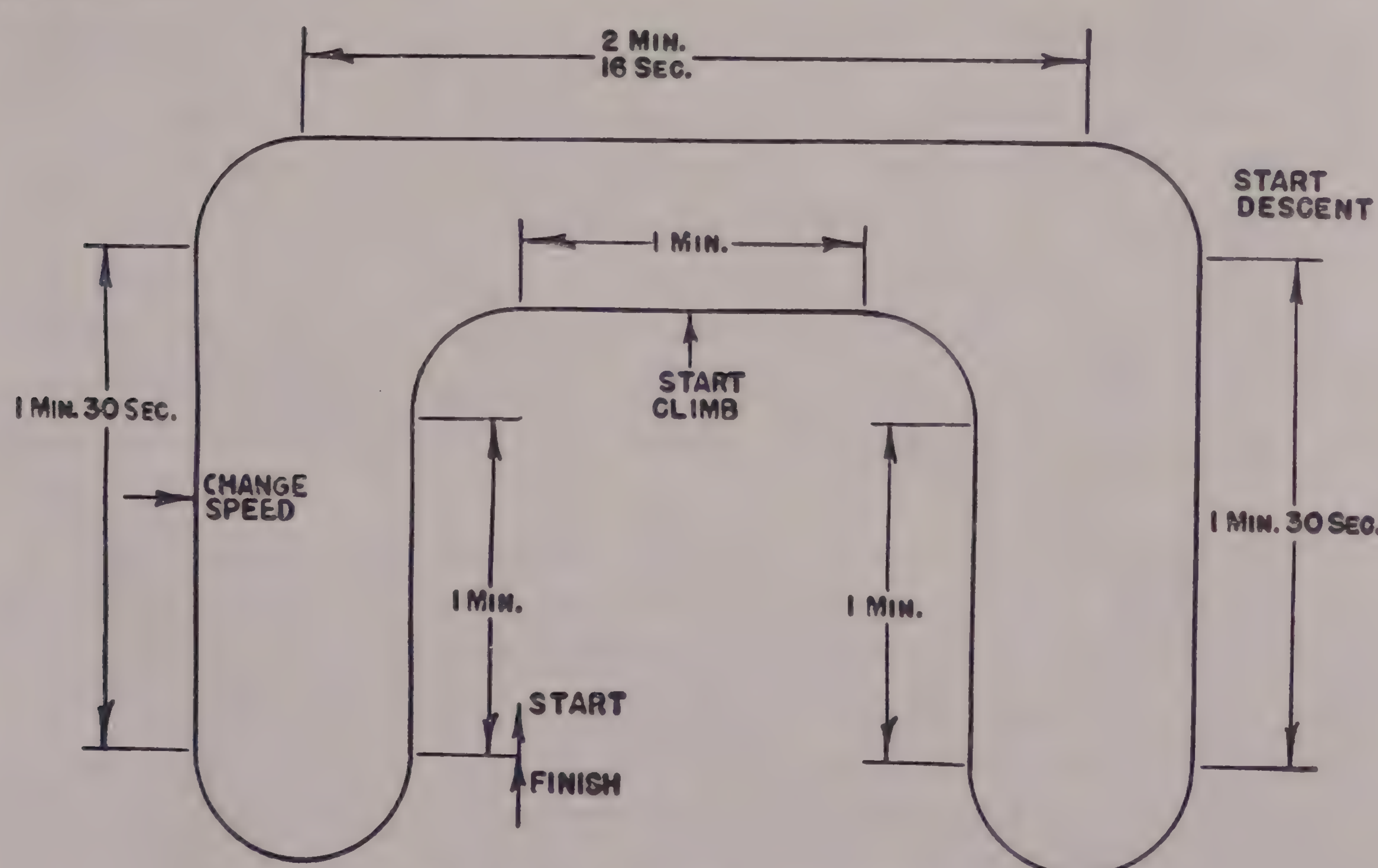


FIGURE 1.—U track, Link instrument trainer.

c. The **U** track as used here is designed to test the student's mastery of previous maneuvers. If he cannot accomplish it properly, his failure will point out the exercise on which he is weak. If he succeeds he is ready to advance to radio navigation practice.

24. Training procedure.—*a*. Due to the fact that in line squalls or other violent atmospheric disturbances it is possible for an airplane to be tossed about sufficiently to upset the artificial horizon and

directional gyro, necessitating control of the plane by the rate instruments, the majority of instructors consider it advisable to complete most of the instrument course with the horizon covered up and the gyro caged. Since the horizon and gyro are very valuable adjuncts to instrument flight, comprehensive instruction in their intelligent use should, however, be a part of the course.

b. Located under the lower right rear of the trainer fuselage is an icing valve. This valve enables the instructor gradually to shut off the vacuum to the airspeed indicator and simulate icing up of pitot. At intervals during the course, without warning to the student, this feature should be used. The student is thus taught to cross check his instruments and compare them with one another.

Chapter 2

RADIO RANGE ORIENTATION

25. General.—*a.* In the minds of many pilots, radio range orientation is a mild form of "black magic," calling for a mysterious and complicated procedure involving geometry, voodooism, and a psychic sixth sense. Other pilots, being more hard-headed but not necessarily more practical, have found or developed a pet system which they fondly believe is a cure-all for any and all situations which may arise in connection with orientation. And there are, of course, numerous pilots who really understand range orientation, its uses, and its limitations.

b. The limitations of range orientation in general and of each method or system in particular are the most valuable facts for the pilot to know. It is vitally necessary to understand the limitations of each system and the specific circumstances under which it will work in order that the pilot may know which method to use under given conditions. The various methods tested, proved, and used by acknowledged expert instrument pilots are outlined in the following paragraphs, along with conditions under which they will and will not work. Any short-cut method which deviates from those which follow should be looked on with suspicion and thoroughly analyzed by an expert before an attempt is made to use it.

c. The complaint often arises that it is unnecessary and possibly confusing to learn so many systems. A little study of the various conditions under which any one system will fail, often with disastrous

results, should convince any common sense pilot of the necessity for a thorough understanding of a subject on which one day his life may depend. Mastery of the several systems will, at first, appear complicated and difficult of accomplishment while under the hood or on instruments. A few hours' practice in the Link trainer, with the charts available for analysis of when, how, and where the errors were made, will show that this is not so. And when the pilot has mastered the various systems to the point where he can promptly choose the proper one for any given set of conditions, he will one day suddenly realize that he is no longer using any system but merely going through the maneuvers that are common sense for that particular set of circumstances.

d. A study of the following text will show that the selection of a particular method is usually based on the pattern of the station being worked. It will also be noted that the bugaboo of range orientation is high wind with its accompanying large amount of drift. It is a fact which can easily be checked by anyone who cares to do so that high winds of velocities of 60, 80, or over 100 miles per hour are not exceptional. Even with modern, fast airplanes such winds produce angles of drift which will cause some systems of orientation to fail on some station patterns; and with the slow planes—150 miles per hour or less—the drift angles become surprising.

e. The necessity of the use of some orientation method is probably most often caused by the fact that dead reckoning navigation has for some reason failed to bring the pilot to his planned destination, and he then does not know where he is. The reason has to be an unknown high wind or unpredicted wind shift. Discounting inability to navigate correctly, it follows then that range orientation will be used most frequently under conditions of high and unknown wind. (Even the existence of such wind conditions, and the resulting drift angles, is doubted by or unknown to a surprising number of pilots.) Again it follows, naturally and obviously, that to be depended on, an orientation system must be one that will work in spite of large drift angles.

26. Definitions.—*a.* Leg, on course or beam, will be construed to mean the equisignal zone, or that directive portion of the radio range identified by the continuous monotone interrupted only by the station identification signal. This zone is about 3° wide.

b. The A and N signals are termed zone or quadrant signals. The edge of a leg, on course or beam, is that strip alongside the beam where the off-course A or N is so faint it can be distinguished only one-fourth to one-half the time.

c. (1) The bearing of a beam is its magnetic bearing as stated in official data, maps, or facility charts.

(2) The inbound bearing is the bearing toward the station.

(3) The outbound bearing is the bearing away from the station.

(4) Heading of a beam is the compass heading which maintains the beam edge.

(5) The area between beams where an A or N is heard is termed zone, quadrant, or sector.

d. (1) Bisector is the direction toward the station which lies in the middle of a zone.

(2) Average bisector is the average of the bisectors of both A or both N zones.

e. Bisignal zone is any area in which both A and N zone identification signals can be heard.

27. Beam bracketing.—*a. General.*—(1) Radio range orientation is the art of finding and identifying a radio beam for the purpose of establishing one's position in relation to the radio range station. After this line of position is established the next step is to track down the beam and follow its right hand edge to and over the station. This latter step is common to and is the goal of all orientation systems. It is also, actually, the most difficult phase of orientation problems.

(2) Properly bracketing a beam enables the pilot to obtain, in the shortest possible time, the heading which will keep him on the right hand edge and thus enable him to fly a straight course to the station. It enables him quickly to determine his drift by comparing the heading with the published beam bearing—the difference being the drift correction.

(3) Since there is almost never a no-wind condition in bad weather, it becomes obvious that the heading required to stay on the beam edge will practically never agree with the published beam bearing. They will not even be close in most instances. Since the drift may be anything up to 40° or more on either side, the heading which will maintain the beam edge may be anywhere within an angle of nearly 90°. Since beams are only approximately 90° apart anyhow, it becomes obvious that the published bearing of the beam has supplied the pilot with practically no information regarding the compass heading he will have to maintain to follow it.

(4) It becomes equally obvious, then, that the pilot who would consider himself skilled at radio range flying (whether orientating from a lost position or merely following beams cross-country) must master a method of bracketing and following a beam which is in-

dependent of, and not materially affected by, wind conditions and drift.

b. Method.—The following described method answers this need:

(1) *Basis of method.*—Upon encountering the beam, continue straight through it, noting the compass heading. When the first opposite off-course signal is received, start a standard rate turn to the left. Continue this turn until back to the edge of the beam (provided, however, that this turn must not exceed 180°). Upon reencountering the beam edge, note the heading and immediately start a standard rate turn to the right. (See fig. 2.) Continue this turn until the first off-course signal on the right of the beam is again picked up. Upon hearing this first off-course signal, again start a turn to the left. (The heading which last took the ship into the beam and the heading noted upon again running out of the beam are the original brackets. Somewhere between the two is the heading which will maintain the beam edge.) Continue the left turn to a heading which reduces the bracket by about 25 percent, then hold this heading until the beam is reencountered. Upon reaching the beam edge, promptly start a turn to the right to a new heading which will reduce the right-hand side of the bracket by about 25 percent. Continue this process, reducing the bracket by about 25 percent with each turn. It will be noted that each pair of turns cuts the size of the bracket in half. The process should be continued until the brackets are reduced to from 3° to 5°.

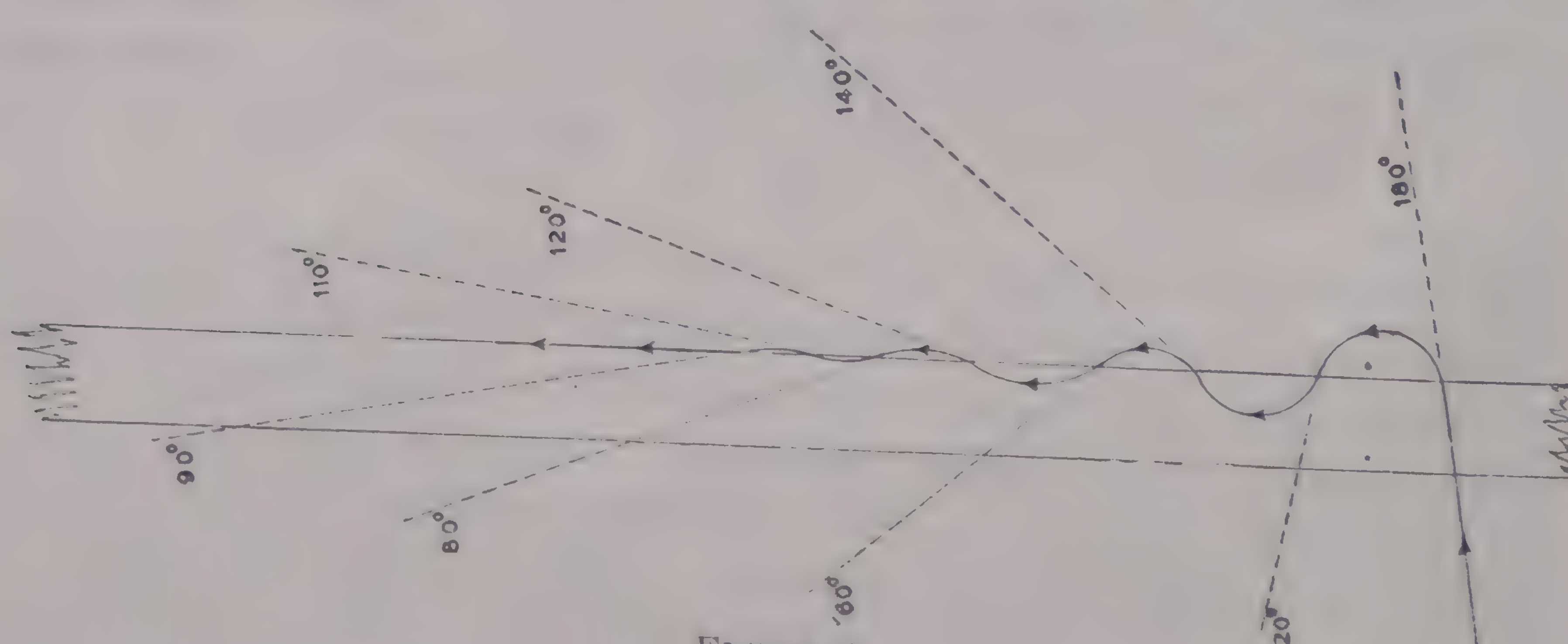


FIGURE 2.

(2) *How it is done.*—(*a*) Upon encountering a beam, note and hold the heading. While riding through the beam compute the reciprocal heading since the ensuing left turn must not exceed 180°. With this value in mind, consider it as a barrier beyond which the turn will not be continued, but not as the object of the turn. The object of the forthcoming left turn is to get back to the beam. (A glance at figure 3 will make clear why the turn should not be more than 180°.)

(*b*) With the barrier heading fixed in mind, the pilot has nothing to do but hold his heading and wait for the first opposite off-course signal. To take a specific example, assume the heading is 180°, and that in entering the beam an N was left behind. Upon the first A received, start a standard rate turn to the left. Listen sharply to the radio signals and as the beam is again just barely reached, note the heading and at the same time start a standard rate turn to the right. Say the heading at this instant is 20°. (The barrier in this case was 0° and was not reached.) It will be noted that a turn of 160° was made and the headings of 180° and 20° are the original brackets (see fig. 2). In the turn now being made it is desired to reduce the size of the bracket by 25 percent. One-fourth (25 percent) of 160° is 40°, so instead of turning to a heading of 180° the turn is continued only to 140° (40° less than 180°). Upon reaching this new heading hold it until the first A is received. Upon hearing the A, start a turn to the left. Since it is desired to reduce the left side of the bracket the same amount as was just done to the right side, this turn will be con-

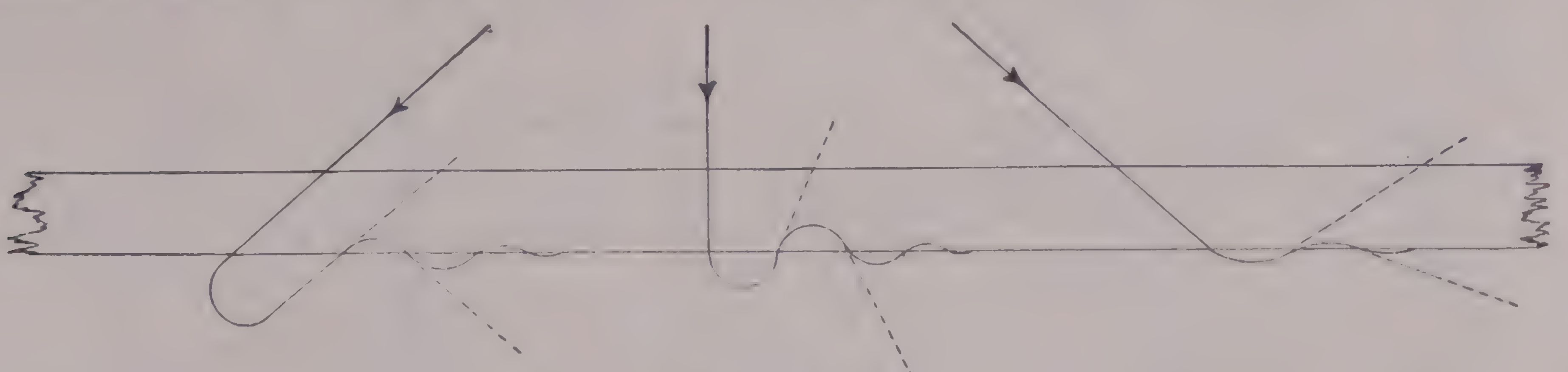


FIGURE 3.

tinued only to a new heading of 60°. Upon reaching this heading hold it until back to the beam edge. It should be noted that the bracket is now reduced from a spread of 160° to a spread of only 80° or just half its original amount. Upon reaching the beam edge, immediately start another turn to the right. The spread of the bracket now being 80°, one-fourth of it will be 20°. So 20° is taken off the heading of 140°, which was the previous right-hand side of the bracket, and the turn continued only to a heading of 120°. This heading is held until the first off-course A is again received. Upon hearing the A, start turning left to a new heading of 80°. (This is stopping the turn 20° before reaching the previous inbound heading of 60°.) Note that the bracket is now reduced to a spread of 40°.

(*c*) Continuing in the same manner to reduce the bracket further, the heading is held until again back at the beam edge when another turn to the right is immediately started. Again taking off one-fourth (¼ of the 40° spread being 10°), this turn to the right will be continued to a new heading of 110°. (The previous outbound heading

was 120°.) Upon again receiving the A, turn left as before, this time to a heading of 90° (10° before reaching the previous heading of 80°). Repeat the process again, reducing the bracket by 5° on each side (the spread now being only 20°), and the bracket is down to only 10°; once more and it is reduced to 5°, and the final landing is found to be 100°.

(*d*) From the above description one might make the mistake of assuming that the beam heading is always the mean of the first bracket. This would be true only if the pilot could make mathematically perfect turns, if his ear was a delicate electrical instrument subject to no error, and if the beam were not interrupted approximately one-fifth of the time for identification signals.

(*e*) If the pilot is slow in recognizing the off-course signal, or if an identification signal occurs at the instant of running off or into the beam, a saw-tooth bracket will result. (See fig. 4.) For example,

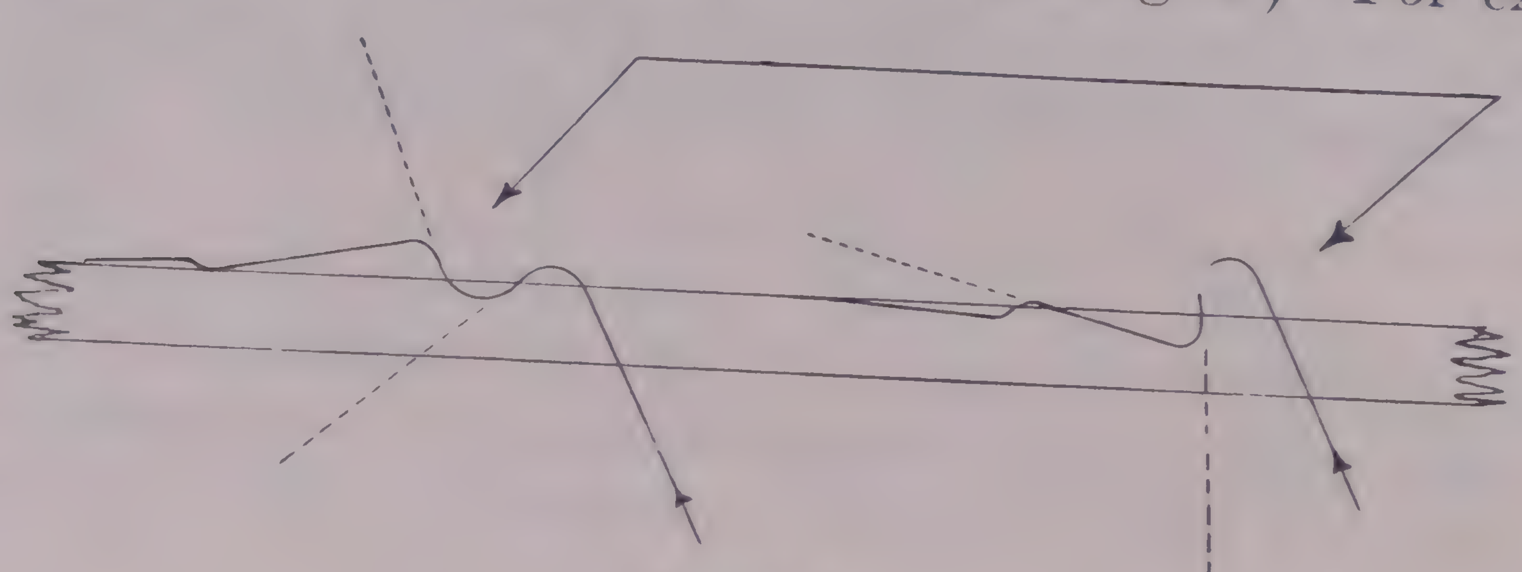


FIGURE 4.

while turning to the right to find the edge of the beam, for either reason given above, the turns which determine the original bracket are often carried too far in that direction. Or if the error occurred while going into the beam the turn to the left would be too great and the bracket "lopsided" in that direction. This condition can be readily recognized when it occurs The effect, as shown in figure 4, is that if the original turn to the right has been too great, it will take a long time to get back to the beam. The next turn to the right to get out of the beam will result in reaching the off-course almost immediately. The situation is easily remedied. If it takes a long time to get back to the beam and only a short time to get out of it, remove very little or none from the inbound bracket. If a long time is taken to get out of the beam and only a short time to get back in, reduce the bracket on the right (outbound) turns little or none. The brackets should be reduced equally on both sides only when the straight flight between turns is approximately equal on inbound and outbound headings. While this sounds complicated it is not difficult to do. It is much easier to demonstrate than describe.

(*f*) The method of bracketing a beam just described is termed "mechanical bracketing." The pilot who has mastered the method can reduce the amount of turning and the time required to obtain a narrow bracket on the beam heading by anticipation and making use of the changing signals. This is particularly true when working within a few miles of the station where the signals are sharp and the changes rapid and distinct. For example, when making a left turn to get back to the beam as in mechanical bracketing, when it is obvious that the background is increasing in strength this indicates that the beam is getting closer. It is needless then to turn further to the left. As soon as the background is definitely increasing, the turn to the left should be stopped and heading noted and held until close to the beam.

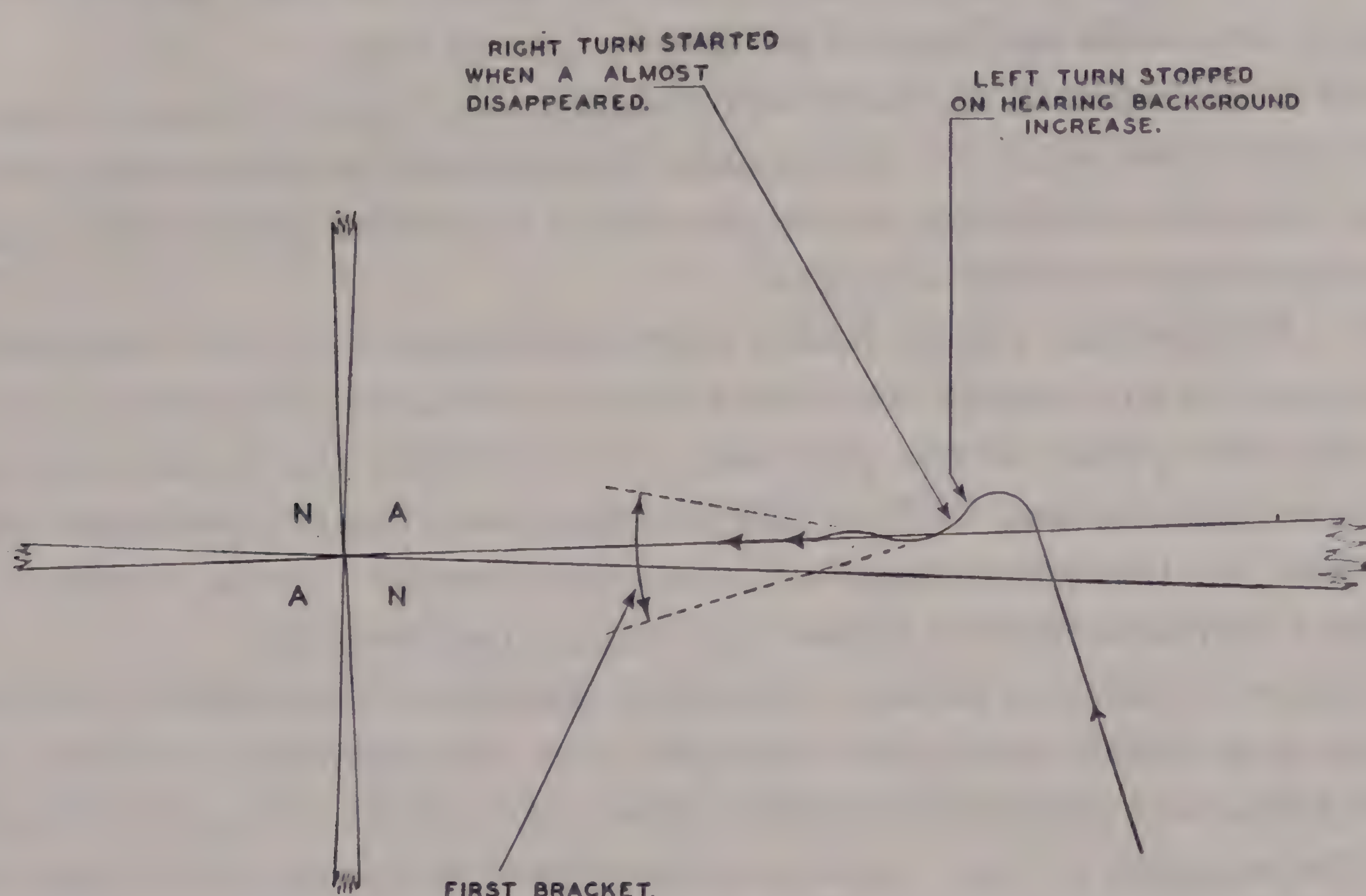


FIGURE 5.

Then, instead of waiting until the actual beam edge is intercepted, the turn to the right should be started just before the beam edge is encountered. In this manner, the original bracket can easily be cut in half; a pilot who is really skillful at bracketing can very often judge the change in signals well enough so that even if approaching the beam at extreme angles his first bracket will be only 15° or 20° (fig. 5). Before attempting to anticipate, the mechanical method should be thoroughly mastered. Even then anticipation of the beam should be done gingerly and cautiously with emphasis on not overdoing it and becoming "beam shy" as a result of starting turns too early when approaching the beam. It is better to anticipate too little and depend more on the mechanical method than to overdo it and lose the beam.

(3) *Advantages of method.*—The method is independent of wind and drift and can be used even if no map or knowledge of the particular station is at hand. It makes possible getting squared away quickly and steadied down on the beam edge, with the drift established, while far enough from the station so that only minor corrections to headings are necessary when close in. This results in being able to follow the definite on-course to the station and consistently to hit definite cones which in turn does away with having to guess at the approximate position when in the vicinity of the station. It permits of arriving in the shortest possible time at the heading which will follow the right hand beam edge and a straight course to the station.

(4) *Disadvantages of method.*—(*a*) *Too much turning and twisting.*—Actually, no more turns need be made by this method; they simply are made earlier and without waste of time.

(*b*) *Too difficult to learn.*—Not unless the pilot, through lack of practice, is so weak on instrument flying that he cannot keep track of or compute headings, or listen closely to radio signals while maintaining control of his airplane.

28. Following right-hand edge of beam.—*a.* After bracketing the beam as previously described and the brackets are reduced 2° or 3°, the next phase of the problem is to maintain the beam edge until close to the station. This will require considerable practice but is essential as the percentage of cones intersected by the student will depend on his ability to follow the beam edge properly.

b. Due to various factors described elsewhere the edge of the beam is not a perfectly clear-cut straight line. Consequently even if the drift remained constant (which it does not), small changes in heading will be necessary from time to time when following the edge, even though the bracketing has been done properly and the brackets are small. The student should learn to recognize and ride the "fringe." This fringe is that narrow path alongside the beam where the off-course signal is so faint that the pilot can distinguish it only about one-fourth to one-half of the time. The occasional leaking in of a faint off-course A or N is also contributed to by slight swinging of the beam, and to a ragged edge produced by small local fades and builds.

c. Most students will display a tendency to remain in the off-course signal too long. If the left-hand side of the small bracket already established does not gradually lead back into the beam after a reasonable length of time, the mistake should not be made of making a series of further small corrections. Rather, apply a 10° or a 15° correction toward the beam, and then when the signal sounds like it would be

impossible to hear more than one or two more off-course letters, remove this large correction and return to the small brackets previously established. Then move both sides of the small bracket 3° to 5°. If the right-hand side of the small brackets does not result in reaching the beam edge within a reasonable length of time (depending on how long the previous outbound heading required to reach the edge), a 15° correction to the right should be applied and then removed when the edge is reached. If good contact with the beam edge is not maintained until close to the station, the last minute or two from the cone is almost certain to produce wild corrections and missed cones.

d. As the station area is approached, the beam narrows. When close enough to the station so that small corrections in heading will take the ship from a slight off-course signal on one side of the beam to an off-course on the other side, the pilot should be content to remain in the middle of the beam and not attempt to find the edge from that point to the cone. The final mile or two is where the insufficiently trained pilot will throw away his chances of getting a good cone. When this close to the station, as indicated by the narrowness of the beam and the sharpness of the signals, all corrections in heading must be made with the airplpane held level. If the ship is permitted to bank, the pilot will hear whatever signal the lead-in is pointed toward. If he reacts to an off-course signal caused by banking, and corrects for it, he will really be off-course when he again levels the ship. When he banks and corrects for this latter off-course, pointing the lead-in out into that quadrant, he will hear a loud, clear signal that often will scare him into wild swings that inevitably result in missing the station. The remedy is simply that when close to the station the beam must be bracketed down well enough so that only small corrections are necessary and *the turns must be flat to avoid distorting signals.*

e. Making flat, skidding turns is not easy, especially "on instruments." A new coordination is required which is entirely different from habits formed in contact flying. It is necessary to make the turns with the rudder and to apply sufficient opposite aileron to keep the wings level. When the new heading is reached it is necessary to continue to hold a certain amount of rudder and opposite aileron until the ship stops skidding. It is definitely recommended that the pilot practice these flat turns without the hood, noting the instrument indications, until he can do it smoothly. To prove to himself the necessity for flat turns close to the station, it is also suggested that the pilot, still without the hood, fly to a position on-course and within 2 or 3 miles of the station, and then roll the ship into a bank first

one way and then the other and note the effect on the signals. He will find that while still in the middle of the beam he can bring in either an A or an N merely by banking one way or the other, and that when he levels off again he is still on-course.

29. Procedure turn-around.—*a. General.*—Turn 45° to the right from the heading that maintained the beam edge. Hold this heading for not less than 45 seconds, preferably 1 minute. Then do a standard rate turn to the left of 180° plus or minus the proper allowance for existing drift. Hold this new heading until the right-hand edge of the beam is reached, then turn left and bracket the beam in the usual approved manner.

b. How it is done.—While maintaining the beam edge, note the difference between the published beam bearing and the magnetic heading. This is the drift correction. For example, assume the outbound published beam bearing is 90° and the heading necessary to maintain the edge is 75°. A standard rate turn to the right of 45 results in a new heading of 120°. Hold this heading for 1 minute. During this time figure what the new heading will be after the 180° (plus or minus) turn is made. In this problem there was a drift correction of 15° to the left. After completing the turn-around the correction will be to the right. Therefore, the left correction must be removed and the right correction added (in this particular problem), making a total factor to the right of 30°. A left turn of 180° from the present heading of 135° would be to a heading of 315°. When the drift factor of a total of 30° to the right is applied, the heading to turn to becomes 345°. At the end of the 1-minute run, then, turn to the left to a new heading of 345°. Hold this heading until back to the right-hand edge of the beam, then turn left and bracket in the usual manner. (See fig. 6.)

c. Advantages of method.—It permits habits to be formed which can be carried out automatically and so require little effort or concentration. It permits the maneuver to be accomplished in the steps "one thing at a time" and so reduces the possibility of confusion. It reduces the possibility of drift interfering with the smooth success of the maneuver.

d. Disadvantages of method.—Takes slightly longer to execute than some other method (but is well worth it).

30. The 90° system.—*a. Basis.*—(1) As soon as the A or N is identified, a heading is taken up perpendicular to the average bisector. Two of the legs are then eliminated from the problem as they are behind and so cannot be intercepted. This heading is held until a

beam is intercepted and crossed. On the first off-course signal after riding through the beam, a standard rate turn of 90° is made to the right. This new heading should take the airplane either back into and through the on-course or deeper into the opposite quadrant. If the on-course is reencountered, the ship passed to the right of the station and the leg on the right is identified. In this case the heading is held for 1 minute after encountering the beam edge. At the end of this minute a standard rate turn of 180° is made to the left. This new heading is held until the far edge of the beam is encountered. The right-hand edge of the beam is then bracketed down and followed to the station.

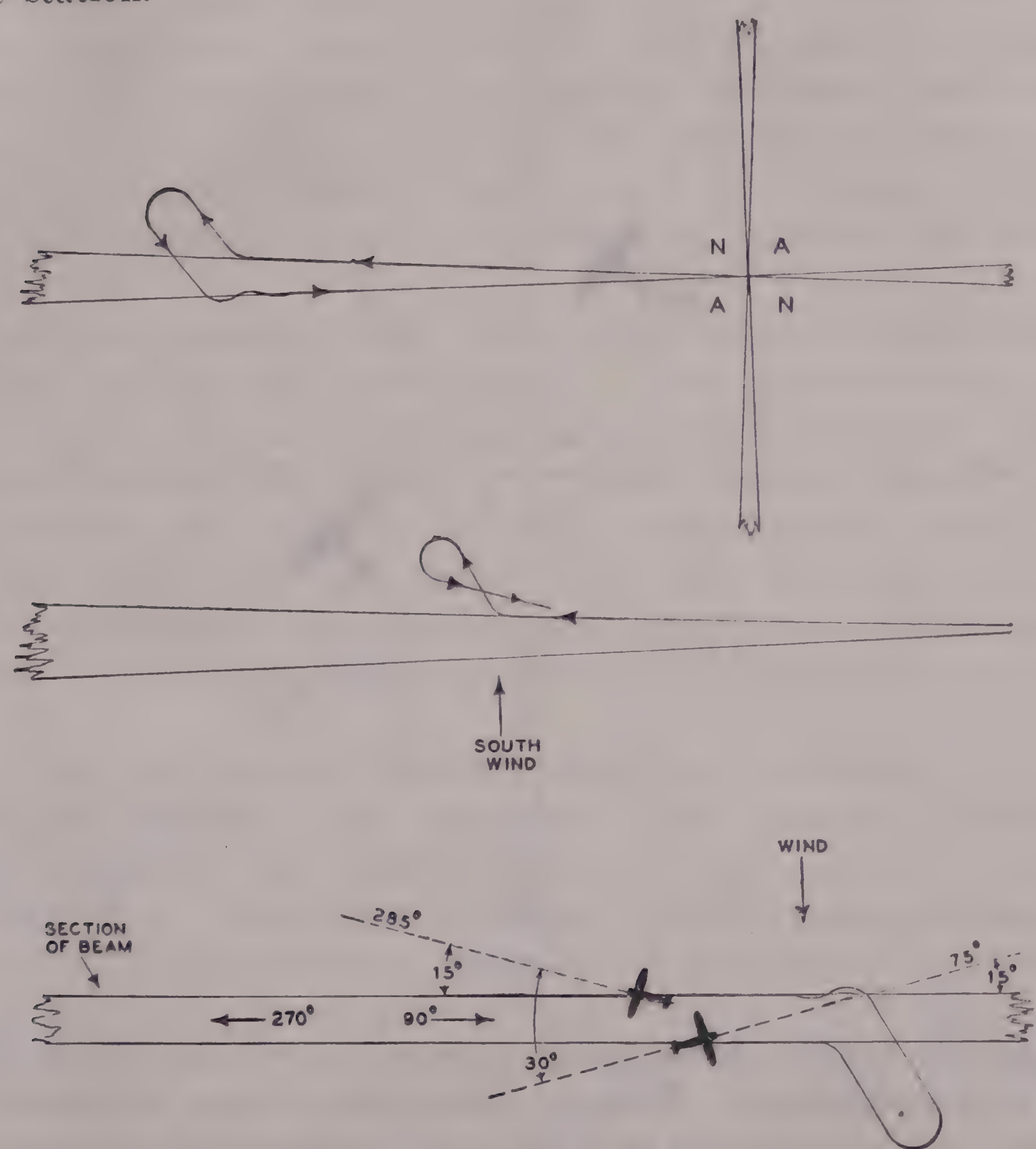


FIGURE 6.

(2) If the 90° turn to the right on first encountering a beam takes the plane deeper into the opposite quadrant, instead of back to the beam, then the ship passed to the left of the station and back to the beam; the left hand of the two possible beams is identified. In this case a standard rate turn of 270° is made to the left. This new heading is held until the far edge of the beam is encountered.

The right-hand edge is then bracketed down and followed to the station. (See fig. 7.)

b. How it is done.—(1) As soon as the signals are heard, check the identification signals to be sure which station is being received. Then listen for a background from the other quadrant. If only a clear A or N is heard, turn the volume up to an uncomfortably loud level and note whether any background can best be detected during identification signals. If a background can be heard, remember the fact

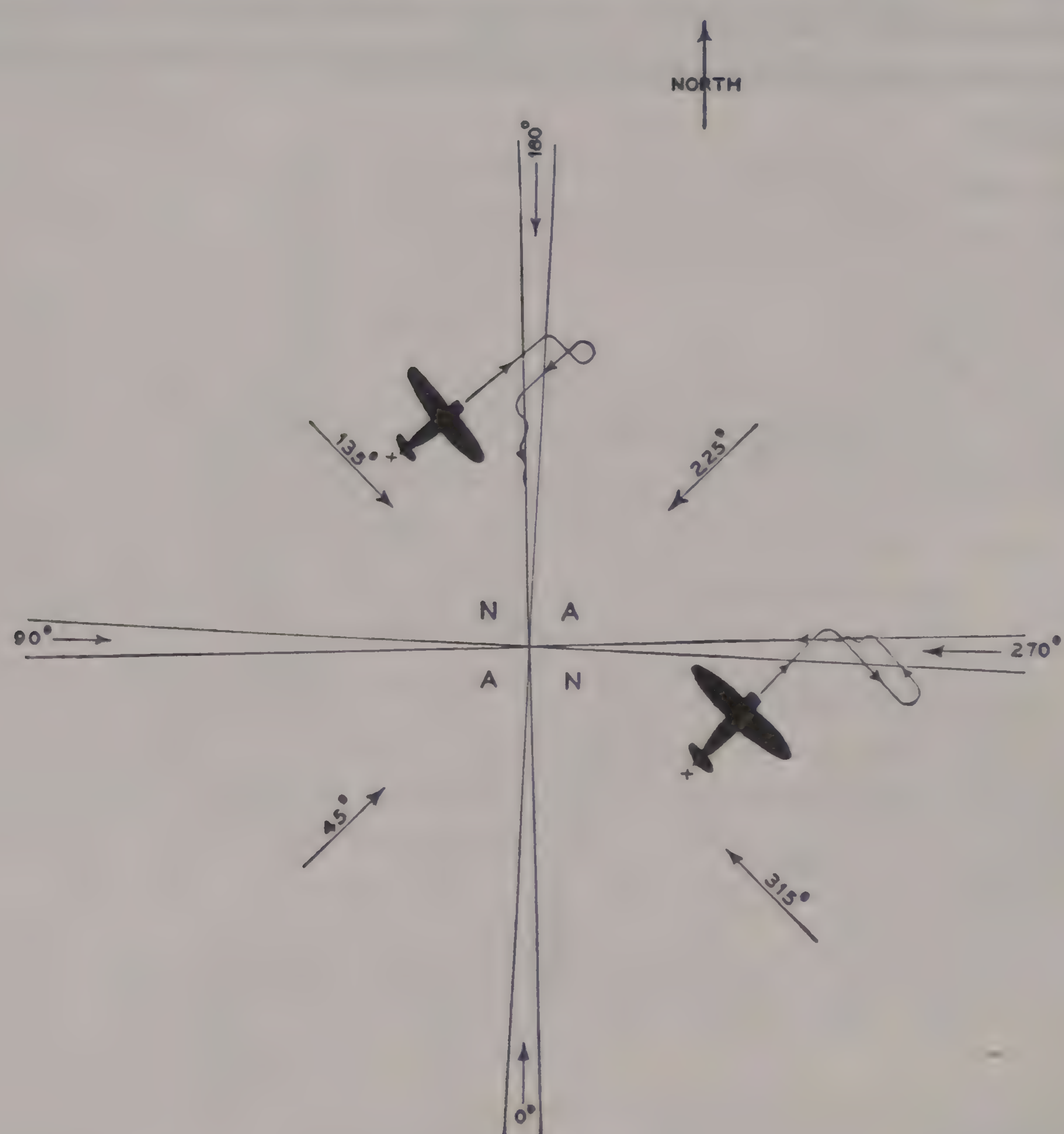


FIGURE 7.

and turn the volume down again to as low a level as can be clearly heard and understood. With as little loss of time as practical, a standard rate turn should be made to a heading 90° to the average bisector of the two possible quadrants. If a background was present at the start of the problem, note whether it is growing louder or disappearing. If the background was noted at first only when the volume was turned to a high level, the volume should be again turned up after 2 or 3 minutes and the increase or decrease of background noted. If the background was present and is fading it is obvious that the ship is going away from the nearest beam, and a 180° stand-

ard rate turn should be made to a heading which is the reciprocal of the previous one but still perpendicular to the average bisector. This heading should then be held until a beam is intersected.

(2) If no background was noted at the start of the problem, the first heading perpendicular to the average bisector should be held until a beam is intersected. Do not change course merely on a suspicion or assumption that there might have been a background. Inspection of figure 7 will show that starting at X two of the four beams (the west and south legs) cannot possibly be intercepted as they are behind. The only problem remaining is which of the two beams in front (the north or the east) will be encountered. The heading is held until a beam is crossed. The 90° identifying turn to the right is started on the first opposite off-course letter heard. While it takes a little longer to ride on through the beam to the opposite side before turning, it will tend to eliminate confusion resulting from trying to work an orientation problem on a false or multiple beam.

(3) After completing the 90° identifying turn to the right the heading is held and the signal change noted. If the problem started in an N quadrant an A will be heard after passing through the beam. If this A becomes increasingly distinct after the 90° turn is made the quadrant and beam are definitely identified. Inspection of figure 7 will show that if the plane had started in the other N quadrant the new heading, after the 90° turn, would have taken the plane back through the beam and back into the N, thus definitely identifying the (in this case) east leg.

(4) After the beam is definitely identified, orientation is accomplished and finished. The remainder of the problem is simply a matter of getting on the right-hand edge of the beam and following it to the station. Experience has shown that the most practical way to do this is as illustrated in figure 7. A simple rule to remember is that when the maneuver leads from "like to like" (from an A back into an A or N back into an N) turn left 270°. It should be noted that this results in the turn back to the beam always being made away from the station thus allowing more room in which to bracket the beam and get squared away before crossing over the station.

(5) When the identifying turn brings the ship back to the on-course the identification is definite, but the heading should be held for not less than a minute after reentering the beam before making the 180° turn so that the turn may be completed before arriving back at the right-hand edge of the beam. This is particularly im-

portant with beginners in range flying as they are very likely not to notice the change in signal while concentrating on making the turn, and will pass out of the beam without being aware of it. By allowing room to complete the turn the student is permitted to do one thing at a time, and so is much less likely to become confused. When going from "like to like" the 270° turn should be started as soon as identification of the leg is definite. The sooner this turn is started the better the results will be. Delaying this turn results

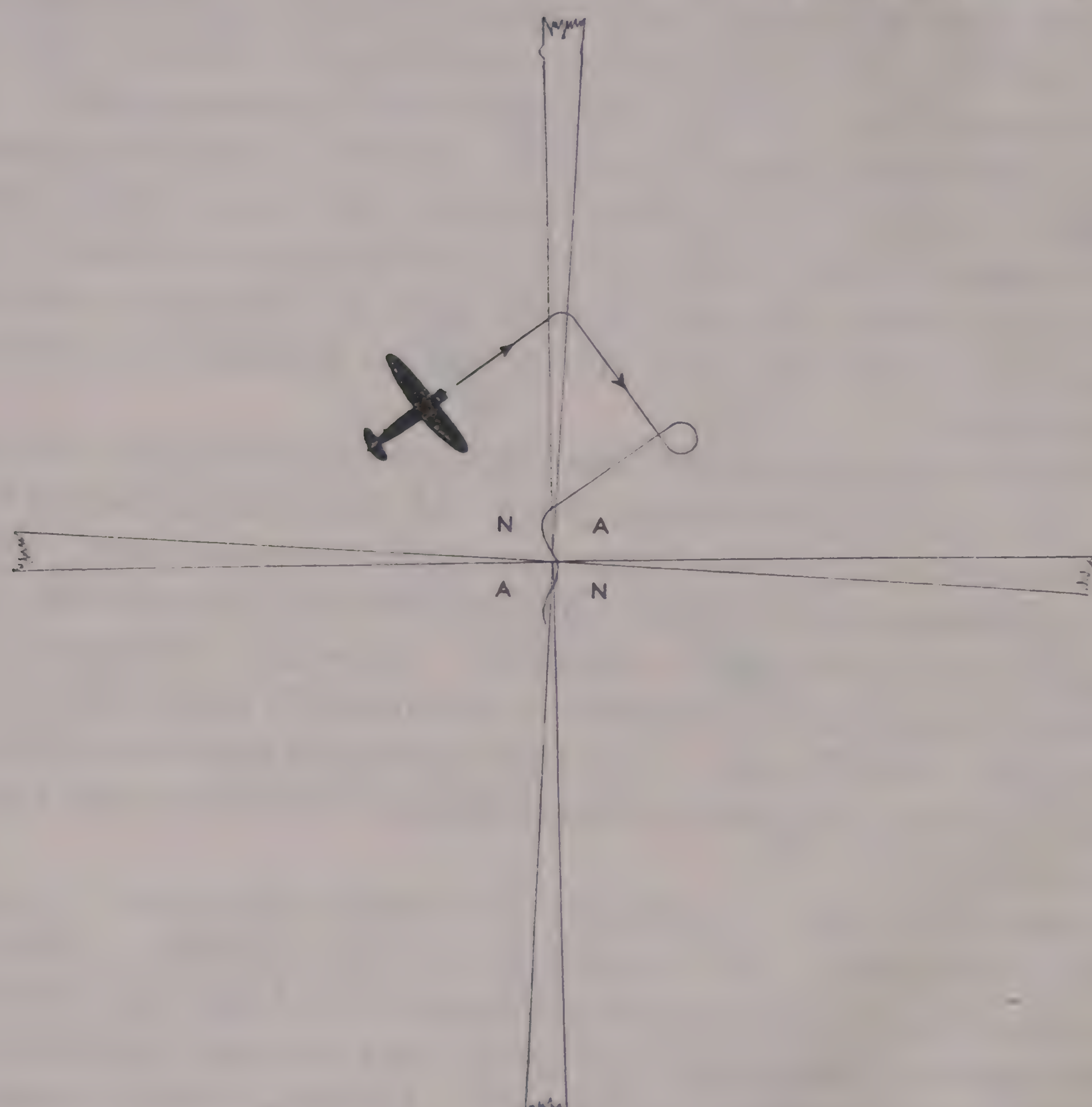


FIGURE 8.

sometimes in getting back to the beam too close to the station. (See fig. 8.) After completing the 180° or 270° turn, the heading is held until the far side of the beam (the side which is to be the right-hand one) is reached. On the first off-course signal heard, the right-hand edge of the beam should be bracketed down in the approved manner as previously described.

c. Advantages.—The 90° system is almost entirely mechanical and so can be learned fairly easily. For this reason it makes a good starting point for the beginner in radio orientation. It has a further

distinct advantage of not depending for its success on changes in signal strength. It can, therefore, be used successfully on range stations where false fades and builds in signal strength are prevalent to an extent that would prevent the use of any fade-out system.

d. Disadvantages.—(1) The time required to complete a problem and reach the station is, in general, considerably longer when using this system than with most others. The system cannot be depended on if the on-courses of the radio range station are more than a few degrees from 90° apart. This statement applies equally to any system that utilizes a 90° turn to identify the beam, with one exception which will be covered later.

(2) Figures 9 and 10 illustrate two examples of the effect of a strong wind on the 90° system. In connection with this it should be borne in mind that during bad weather it is frequently impossible to obtain "winds aloft" reports. It should also be strongly borne in mind that the most frequent reason for a pilot becoming lost is the existence of strong, unpredicted winds at flight altitudes.

(3) Figure 9 shows the effect of a strong wind on the 90° system even on a "square" station. It will be seen that while the problem was eventually completed a considerable length of time was required. It should be noted that at a great distance from the station it would be easily possible to run out of range of the station before reaching the beam. Figure 10 illustrates the result of attempting to use this system in a squeezed or scissor station. The dotted line shows the track the pilot would think he was making, and the solid line shows the actual results. In the open quadrant the beam would never be intersected. In the narrow quadrant, having drifted into the N the pilot would believe himself to be on the northwest leg instead of the northeast, thus receiving false information that would be worse than none at all. In this case if the pilot succeeded in getting on the leg, he would undoubtedly follow it away from the station and eventually run out of gas. Sure, "he should check the fade." But this is the 90° system being used, the pilot thinks he is on the northwest leg because of drifing into the N (remember, he doesn't know about the drift), the compass heading which keeps him on the beam is approximately that of the inbound bearing of the northwest leg, he has an A on his right, and he is convinced he is on that northwest leg. When radio fades he will be more likely to blame it on the battery or the crew chief than to suspect that he is definitely wrong.

(4) There are enough conditions under which the 90° system will not work to make it obvious that other systems must be learned.

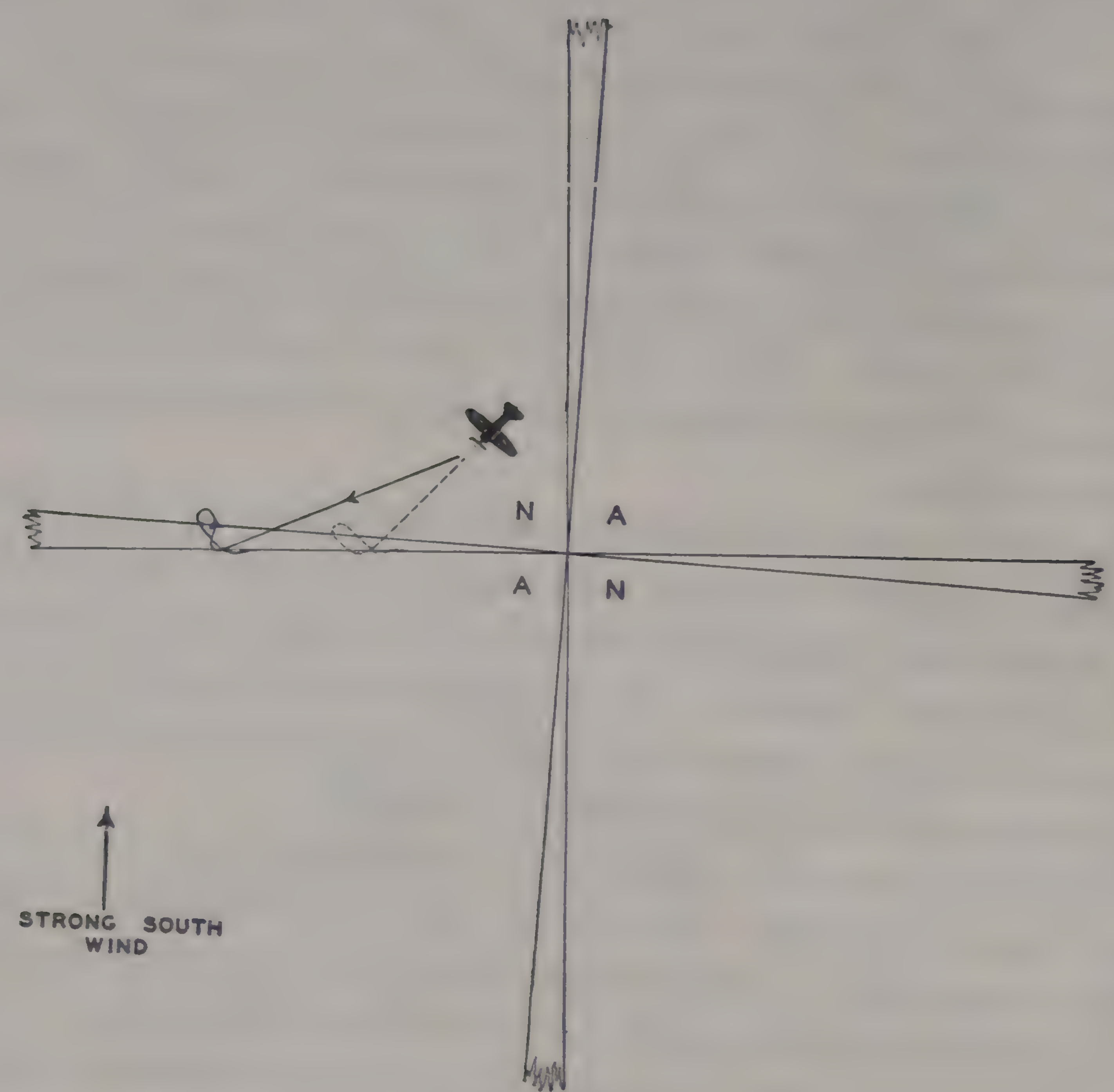


FIGURE 9.

FIGURE 10.

31. True fade-out system.—*a. Basis.*—(1) The basis for the true fade-out system is exceedingly simple. When the radio range signals are received, turn to a heading parallel to the average bisector of the two possible quadrants. Turn the radio volume as low as possible consistent with clear reception. Hold the heading for not less than 5 minutes. If the signal strength is fading, turn 180° and hold the heading until a beam is intersected. If the signal strength increases on the first bisector heading, continue until a beam is crossed.

(2) Upon reaching a beam fly through it and on the first opposite off-course signal turn left and bracket the beam in the usual manner as described under beam bracketing. Recheck for the fade or build. If the signal strength is increasing, continue on to the station. If it is fading do a procedure turn-around and continue to the station. (See fig. 11.)

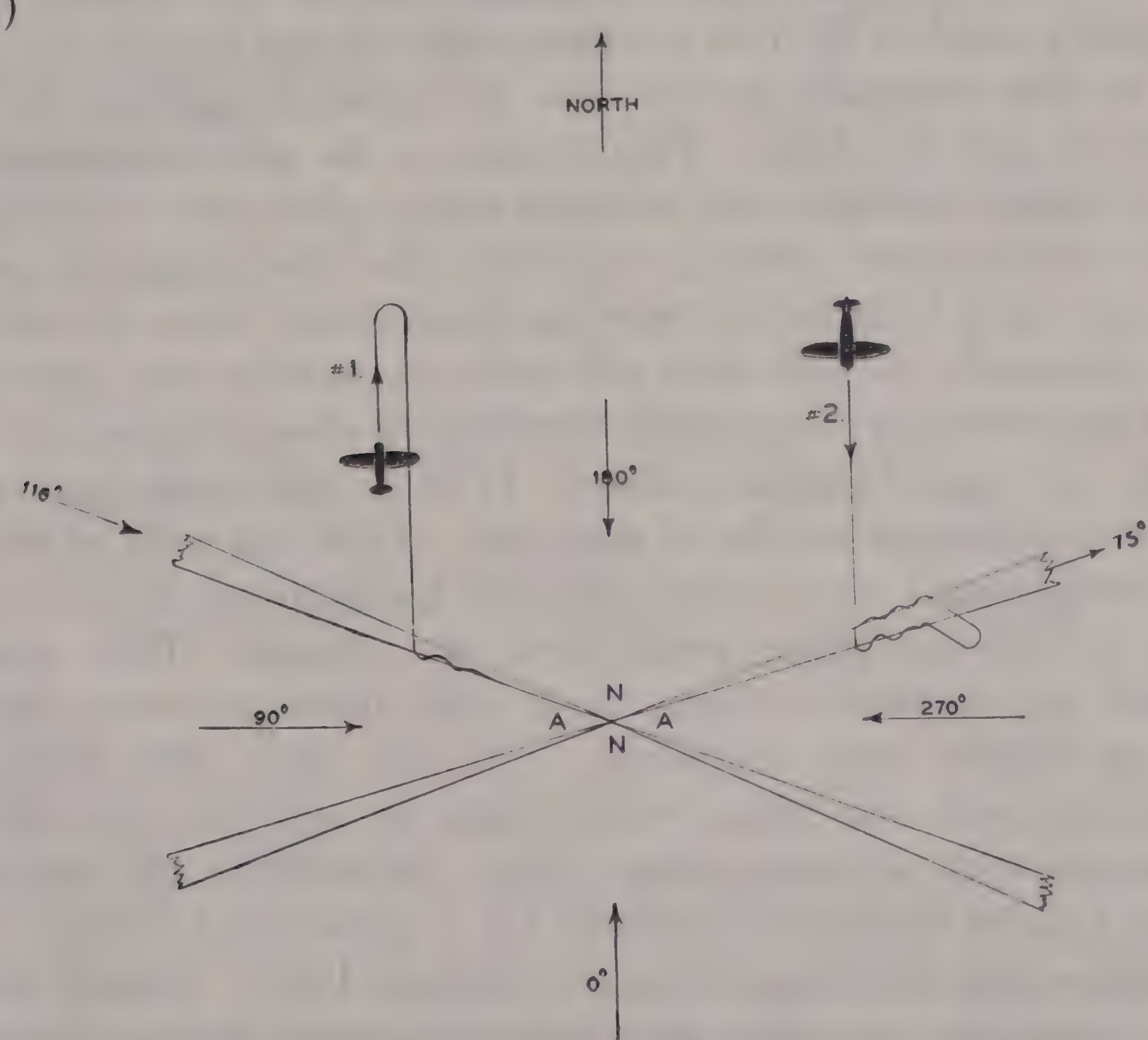


FIGURE 11.

b. How it is done.—(1) Upon starting the problem, turn the radio volume as low as possible and still read the signals. This is important as the lower the volume the easier it is to detect small changes in volume; and the less time will be required to complete the problem. Turn to the nearest of the two average bisector headings of the quadrant being received. (In certain cases it is desirable to turn to a certain one of the two possible headings. This will be covered later.) Hold this heading until there has been a definite

change in volume. If the signal is building, continue until a beam is intersected. If the signal strength appears to be fading make sure that it is really fading before assuming the station is behind and a 180° turn in order. False fades sometimes occur, and a fade over a period of less than 5 minutes should not be accepted. If over mountainous country it is advisable to make a second 5-minute check of the fading before turning around. During such a 10-minute test small fades and increases may have occurred, but the average volume is what must be considered. It is better to spend a few extra minutes at this point making sure of the facts than to turn too early and then worry whether the signal actually had been fading and perhaps be led into turning around again and possibly winding up by becoming hopelessly confused. It is a peculiar fact after a fade has been proven and a turn made so the pilot is headed toward the station, that he will usually need to fly two to three times as far toward the station before he can recognize the increase in signal strength as he had to fly away to get the fade. This failure to be able to recognize the build in signal strength has worried many pilots into turning away from the station and wasting valuable time reworking the problem. Make sure of a fade before turning around and then do not worry if the increase in volume does not occur as soon as was expected.

(2) The success of this system depends on close judgment of signal strength, not signal characteristics. If in a wide open quadrant the signal characteristics can be of some aid. If at the start of the problem a background was heard and this background faded it would appear to indicate going away from the station. This cannot be depended on, however, except in a wide quadrant and even then should be viewed with suspicion. (See fig. 12.) The dotted lines indicate the track the plane would make in still air; the solid line, what occurs with a strong cross wind. In position #1 the plane is properly headed toward the station but a cross wind drifts is out of the background (indicated by the dashed line). Signal strength will be increasing properly but the background fades out entirely. Many a pilot has been known to "bite" on this one and turn away from the station. In position #2 (fig. 12) it will be seen that while perhaps possible, a great amount of drift would be required to drift the ship out of the background while headed toward the station. Therefore, if in an open quadrant and the background faded it would be probable that the station is behind, but the build or fade should also be checked.

(3) Upon reaching a beam, fly through it and on the opposite side turn left and bracket the beam edge. *Do not assume which leg will*

be intersected. Such an assumption, once planted in the mind, is difficult to get rid of in the 50 percent of the cases where it is wrong. Follow the simple rules and bracket the beam without worrying about which one it is.

(4) After the brackets have been narrowed down to only a few degrees, turn the volume down and check for fade or build just as was done in identifying the sector. If the volume increases, the leg is identified as the one which was on the right of the station as the bisector was being flown toward the station. If the volume fades, the leg is identified as the one on the left and the plane as going away

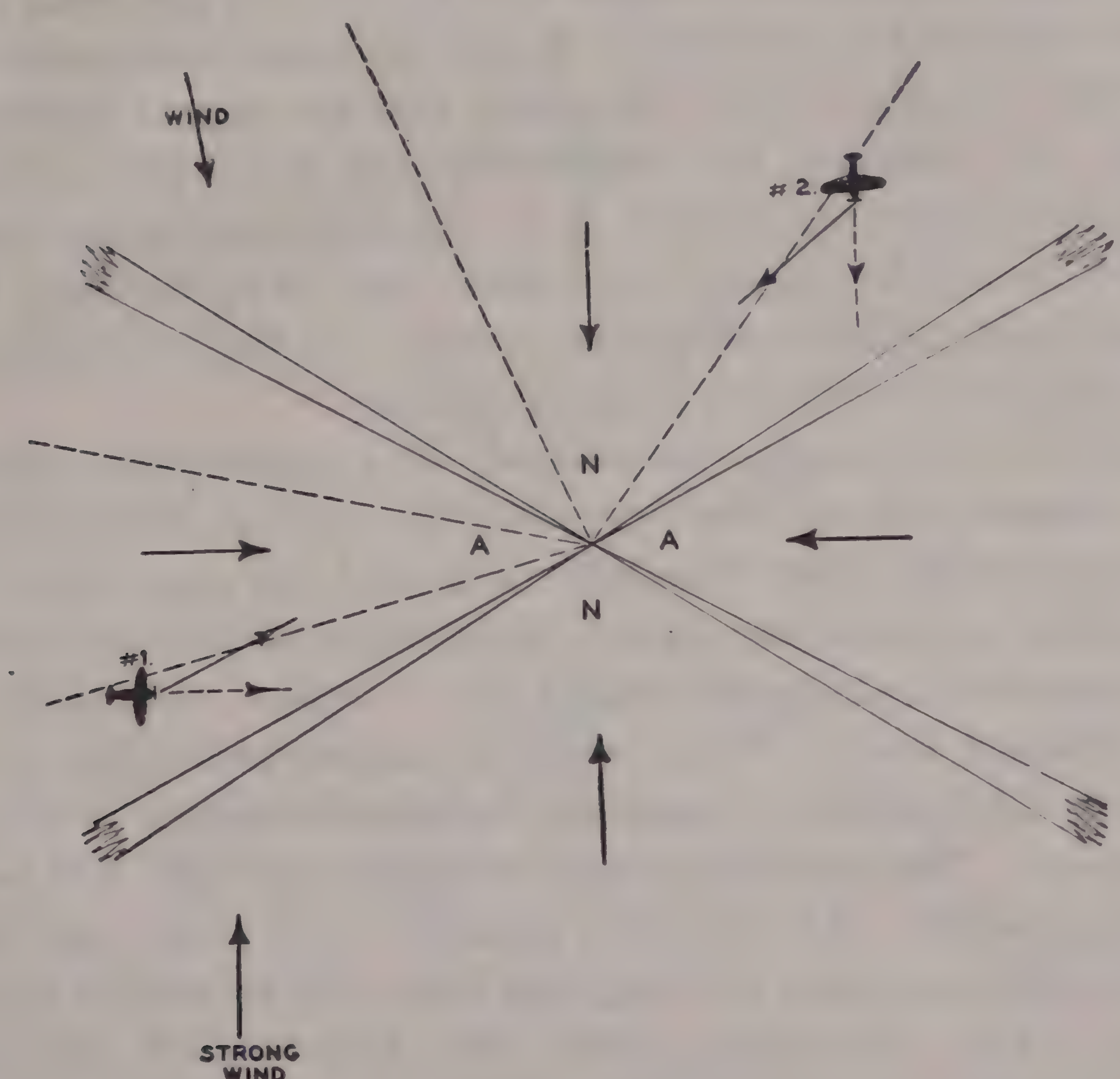


FIGURE 12.

from the station. Do a procedure turn-around and follow the right-hand edge to the station. *Do not at any time compare the compass heading with the published bearings of a beam and, if they happen to agree approximately, be fooled into thinking the beam is definitely identified.* It is a sucker stunt, but every now and then another pilot "bites" on it and gets killed.

(5) To illustrate the reason for the above refer to figure 11. The pilot naturally does not know whether he is in position #1 or #2. He has no way of knowing which beam he is going to intersect. Assume he is at #1 and has a strong north wind. When he intersects the beam he turns left and brackets it. He finds that to stay on the beam he must hold a heading of approximately 75°. He does

not know about the drift. The compass heading agrees with the published beam bearing and he has an A on his right, so obviously (he thinks) he is on the northeast leg and turns around. Suppose he has been in position #2 with a strong south wind. After bracketing the beam he finds it necessary to hold a heading of approximately 115° to stay on course. Comparing this compass heading with the published beam bearing he assumes he is on the northwest leg and is probably quite happy about it all. The compass agrees and there is the proper A on the right. The chances are excellent that he will be planning the things he is going to say to somebody about the way his radio keeps fading out long before he realizes just who is wrong.

(6) The leg can be identified. In the example above while following the beam with an A on the right and the signal fading (going away from the station), the ship could only be on the northeast leg. The only other position with an A on the right and going away from the station would be on the southwest leg. Approaching from the north quadrant (approaching the station on the southerly bisector heading) this leg would not be intersected.

(7) As was previously mentioned, it is sometimes desirable to choose a certain one of the two possible average bisector headings. For example, if the pilot received an A and his map shows that the west A sector extends out over a lake, it is advisable to select the easterly bisector heading so that if he is in the west sector he will be flying toward land. When using a station which has a crowfoot pattern it is advisable to choose the in-bound bisector heading of the largest sector. The rate of change of signal strength will be slow in such a large sector. If the pilot actually is in that open quadrant, the several minutes spent proving the fade will be taking him toward the station. In a crowfoot pattern, the bisectors of each quadrant differ considerably from the average bisector. On such a station it is advisable, after identifying the sector, to turn to the bisector of that particular quadrant.

c. Advantages.—The system will work on any station pattern (square, scissor, etc.). It is not appreciably affected by drift. In most cases it can be completed in considerably less time than the 90° system. It is the only range orientation system that can be depended on in wide open quadrants.

d. Disadvantages.—Without considerable practice it is difficult for the pilot to recognize small changes in signal strength. During heavy static it is difficult for even experienced instrument pilots to recognize the changes in a reasonable time. The system cannot be depended on in some territories where mountains, ore deposits, etc., cause false fading over wide areas.

32. Parallel system.—*a. Basis.*—The basis for the parallel system is very simple and very similar to the true fade-out system. When the range signals are received, turn to a heading parallel to the average bisector of the quadrant signal being received. Turn the volume as low as can be clearly heard and check, over a period of at least 5 minutes, whether the signal strength is increasing or decreasing. For example, assume an N is being received from the station in figure 13. The average bisector is either north or

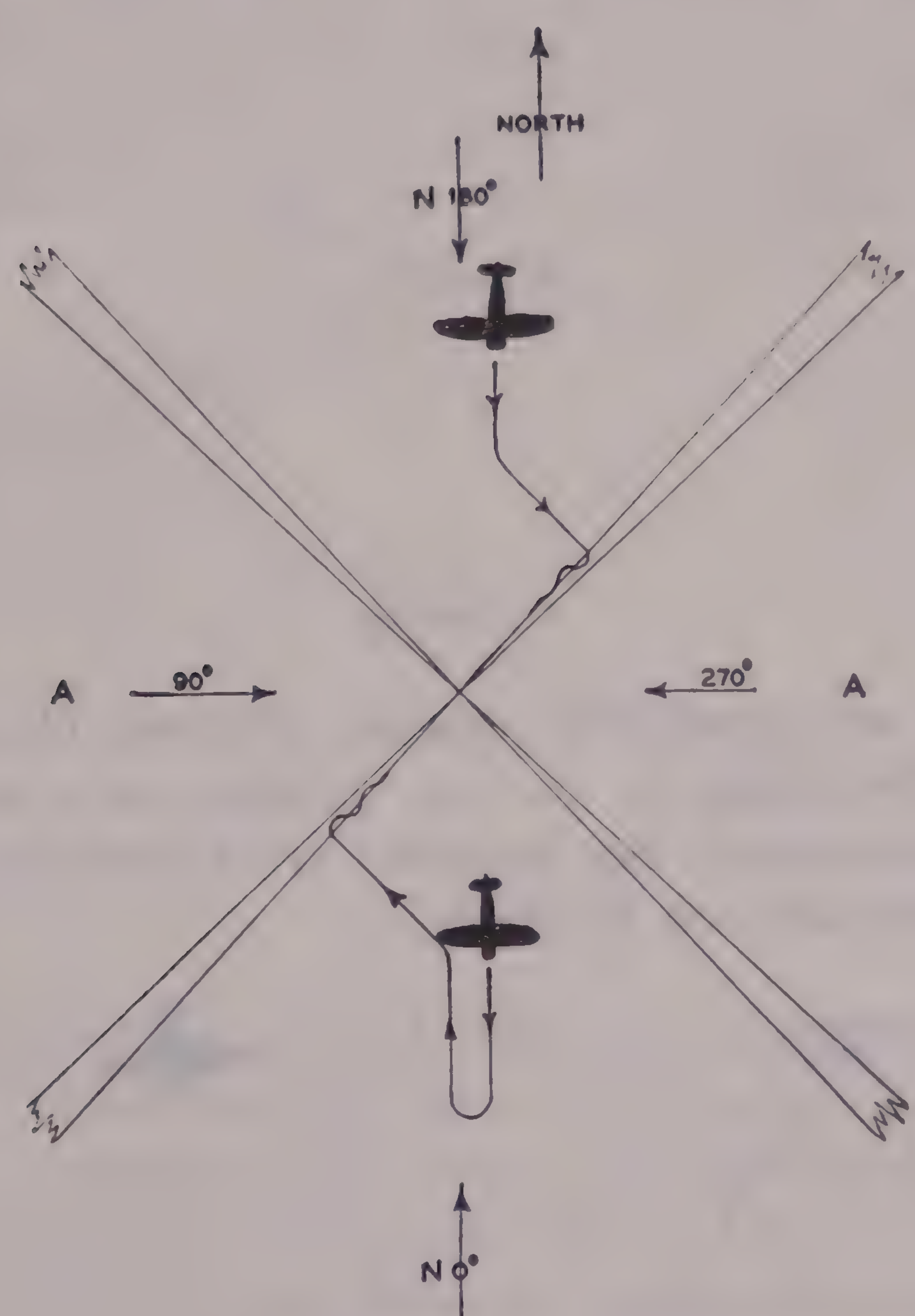


FIGURE 13.

south. Assume the south heading is selected and the volume fades. The plane is, then, in the south quadrant. If on the south heading and the volume builds, the plane (in this example) is in the north quadrant. If the volume fades, turn to the reciprocal heading and fly toward the station for the same length of time as was flown away from it while checking the fade. Then assume a heading parallel to one of the two beams that are in front in order to intersect the other beam. (See fig. 13.) On intersecting the beam, turn toward the station and bracket the beam in the approved manner.

b. Advantages.—The system is easy to remember. Under certain conditions it simplifies identifying which leg is intercepted. In conditions under which it will work, it is a little faster than the true

fade-out. Under workable conditions, it allows the pilot to choose which leg he will intercept.

c. Disadvantages.—The system is easily disrupted by drift and cannot be relied upon under conditions of unknown drift except

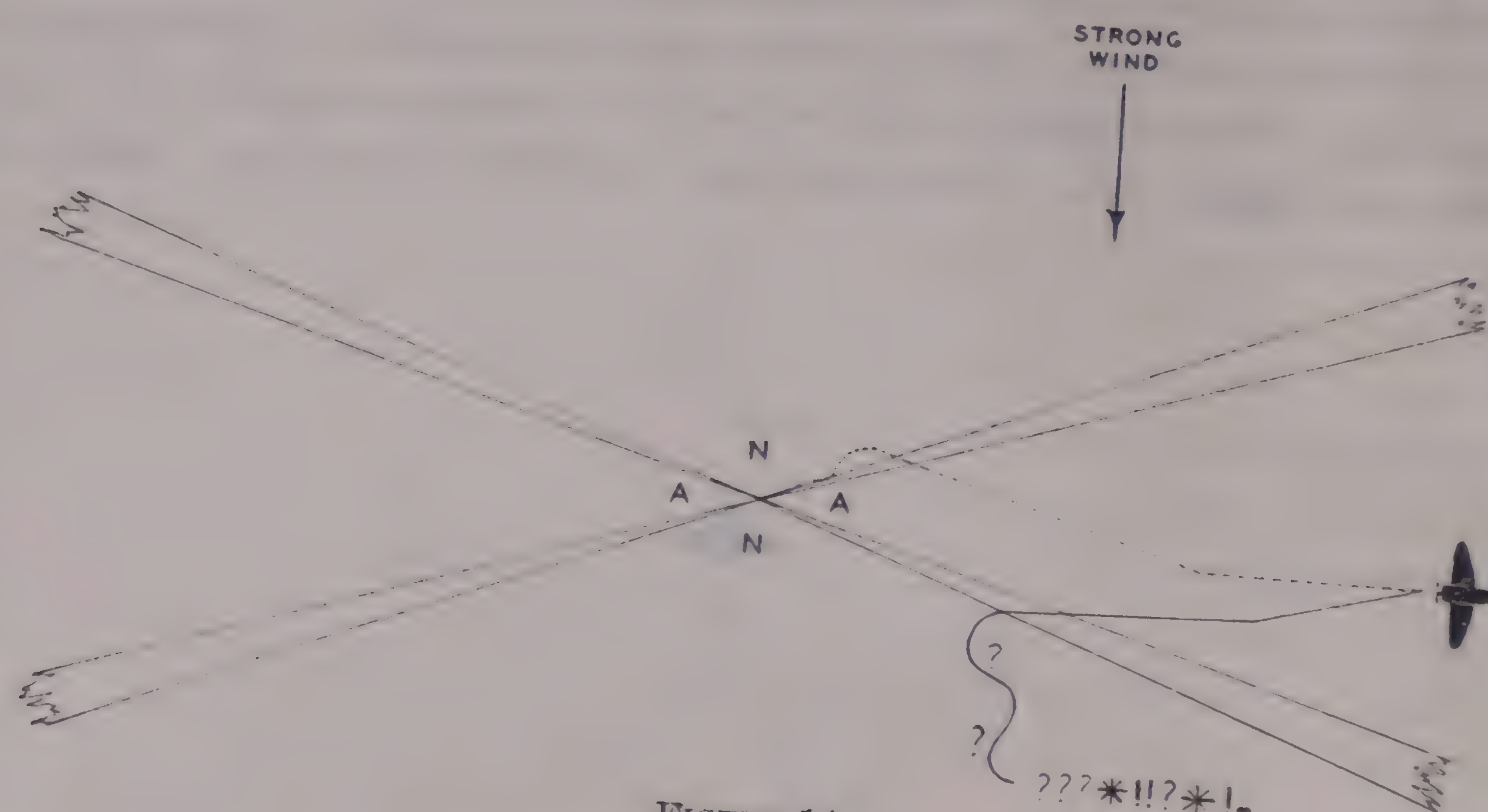


FIGURE 14.

on stations that are practically square. Figures 14 and 15 illustrate the result of attempting to use the method on a squeezed station. The dotted lines indicate the intended track and the solid lines the actual track when affected by drift.

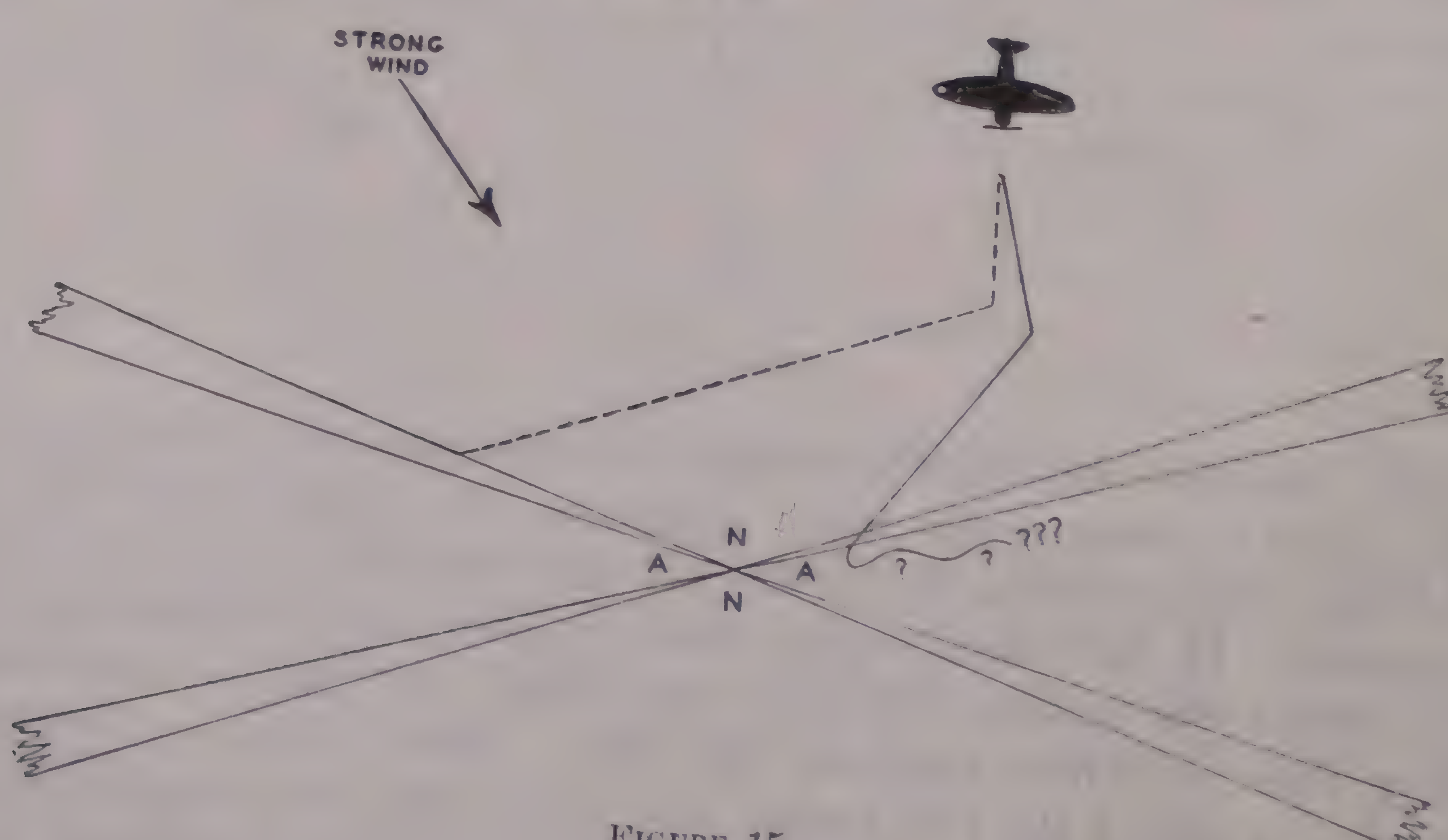


FIGURE 15.

33. Parallel-perpendicular system.—*a. Basis.*—The basis of this system is similar to the parallel system. The quadrant is identified in the same manner as in the parallel and the true fade-out. Then, instead of being influenced by the beam it is not desired

to hit, a heading is taken directly toward the desired beam (perpendicular to it). Upon crossing the beam a turn of 45° is made away from the station. This heading is then held for from 45 seconds to a minute, then a turn of 180° is made also away from the station. (See fig. 16 (A).) This heading brings the plane back to the beam at a relatively easy angle from which to bracket down in the usual approved manner headed toward the station. All turns are at a standard rate.

b. Advantages.—This method may be depended on except in an open quadrant (beams more than 90°). In a squeezed quadrant it will stand as much drift as any system. It has all advantages of the parallel system plus being workable in a squeezed quadrant.

FIGURE 16.

c. Disadvantages.—The method cannot be depended on in a quadrant where the beams are more than 90° apart. An extra turn is used in turning to get onto the beam. If sufficiently far from the station to allow room to bracket, the 45° and 180° turn away from the station may be eliminated, however, and a turn made toward the station followed by the usual bracketing. Figure 16 (B) illustrates why the system will not work in an open quadrant.

34. Fade-out 90° system.—*a. Basis.*—The quadrant is identified by the fade-out method as in the true fade-out and parallel systems. The inbound bisector heading is flown until a beam is intersected. The beam is crossed and upon receiving the first opposite off-course signal a 90° turn is made. (This turn may be made either way without affecting the efficiency of the system, but it is recommended that it be made to the right for the sake of standardization.) When headed toward the station on the bisector heading there is a beam on the left and one on the right. If the 90° turn to the right brings the ship back into the same quadrant, the left beam was the one intercepted. If the identifying turn takes the ship deeper into the opposite quadrant, the beam intercepted was the one on the

right. (See fig. 18.) As soon as the beam is identified a turn to the right (away from the station) is made to get back to the beam. If the beam on the right was intercepted, the turn should be of 180°; if the left beam, 270°.

b. Advantages.—When it will work it is quicker and easier than some other systems. Its best use is in a squeezed sector to avoid having to bracket the beam and then identify it by the fade as in the true fade-out.

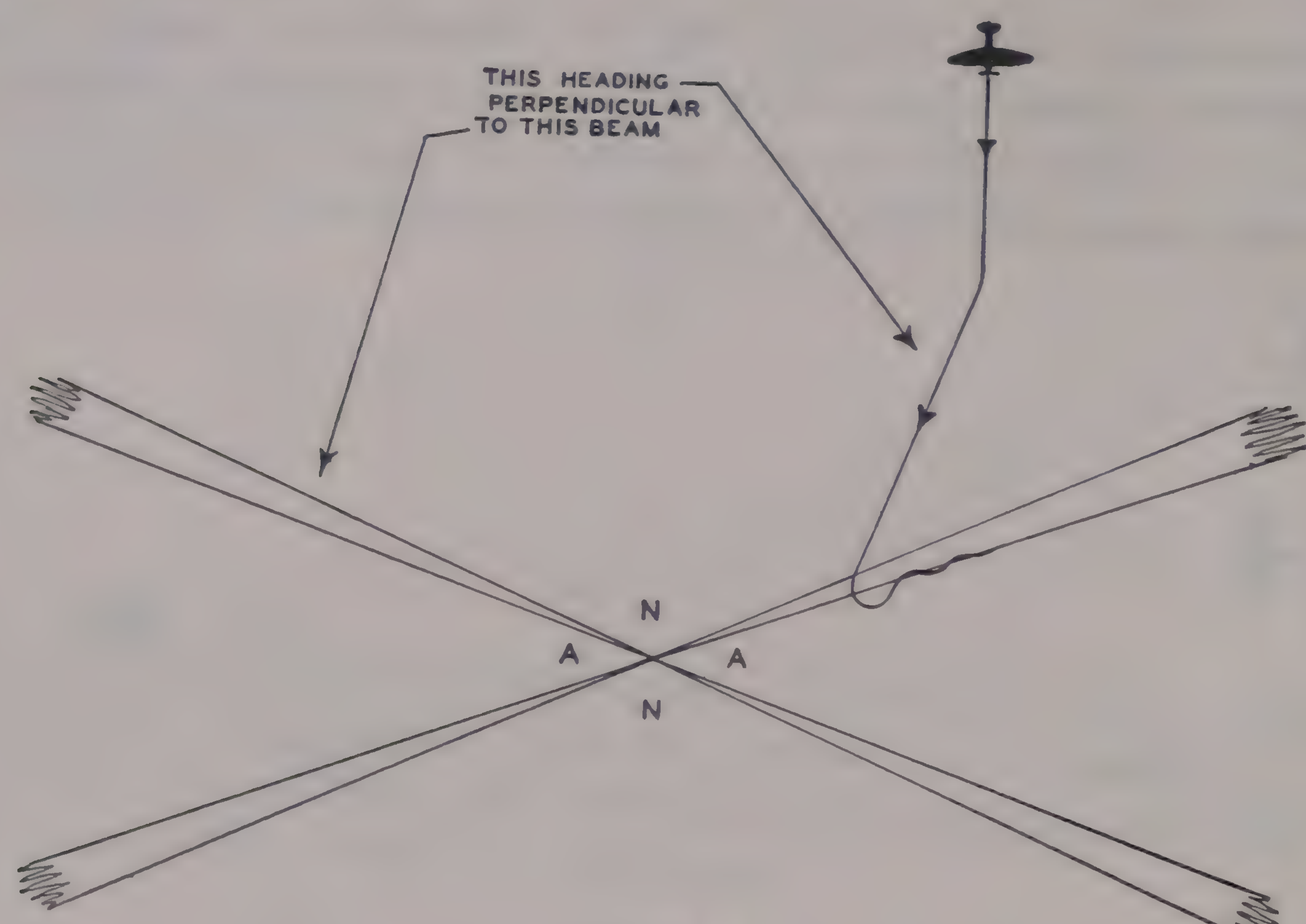


FIGURE 17.

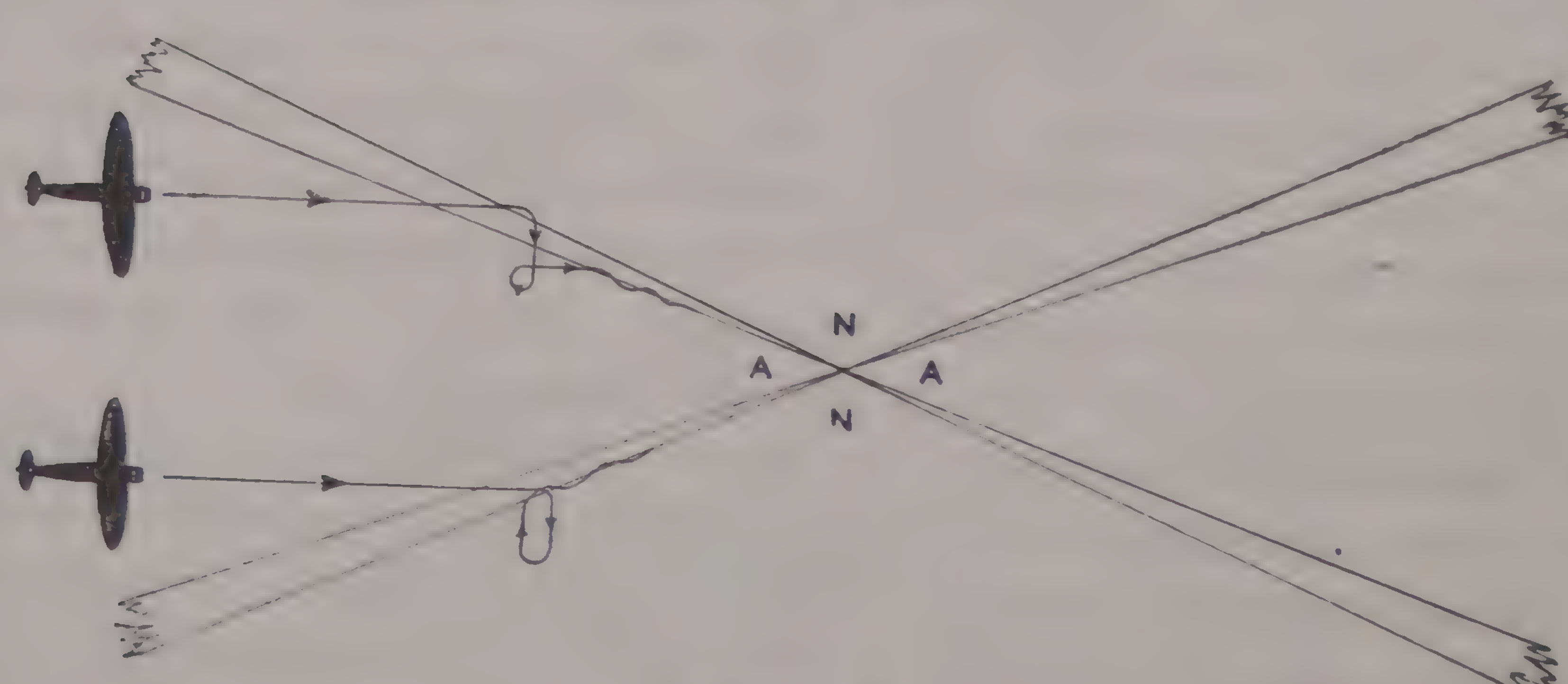


FIGURE 18.

c. Disadvantages.—It cannot be depended upon in an open quadrant. (See fig. 19.) Quadrant identification is difficult in sections where false fades or builds in signal strength are prevalent. It has most of the disadvantages of both the 90° system and the true fade-out system. It should be recommended for use only in a squeezed quadrant.

35. Unknown station system.—*a. Basis.*—The basis of the system is simple. It is designed for use where a map of the station being received is not available and where nothing is known about the pattern of the beams. It is an adaptation of the true fade-out system, and the average bisector heading is flown and checked for a fade or build. Since the station pattern is not known, the approximate average of all the average bisectors is flown. This heading is 80° in an A and 350° in an N or their reciprocals.

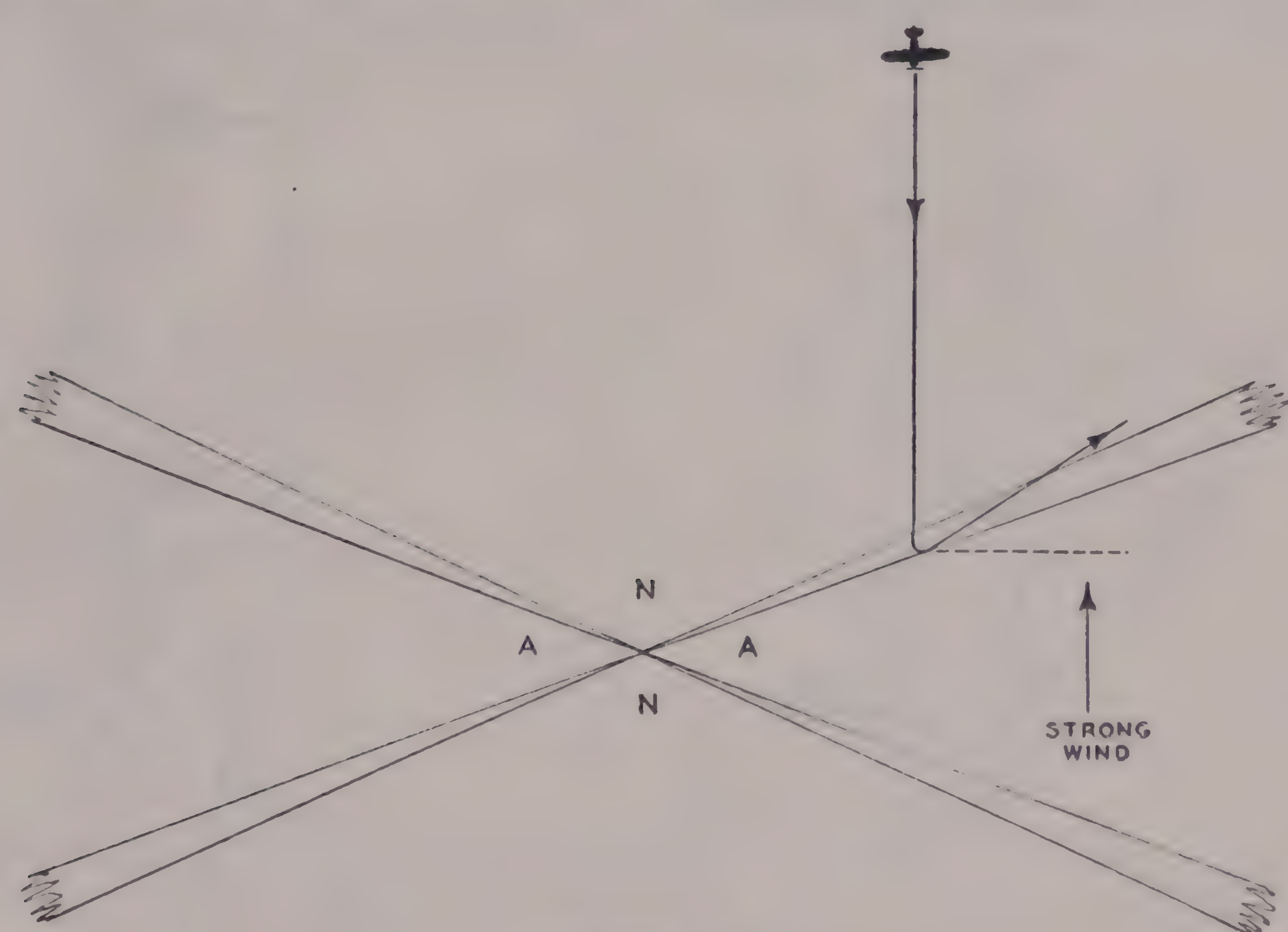


FIGURE 19.

b. How is it done.—(1) When the station is tuned in, turn to the proper heading for the letter being received. Note whether there is a background and turn the volume low as in the fade-out system. Check for a fade or build over a period of at least 5 minutes. If the background fades pay especial attention to signal strength, and if the strength is either fading or remaining constant turn 180° as it is evident the nearest beam is being left behind. If, however, the volume increases, continue until a beam is intersected. If there is no change in signal strength or if there is no change in the background, after several minutes of flight turn 90° and recheck for fade or build.

(2) Figure 20 illustrates that, regardless of station pattern, one of the "average of all bisector" headings points toward a beam. In still air this is theoretically true except when at considerable distance from the station and under certain conditions as shown in

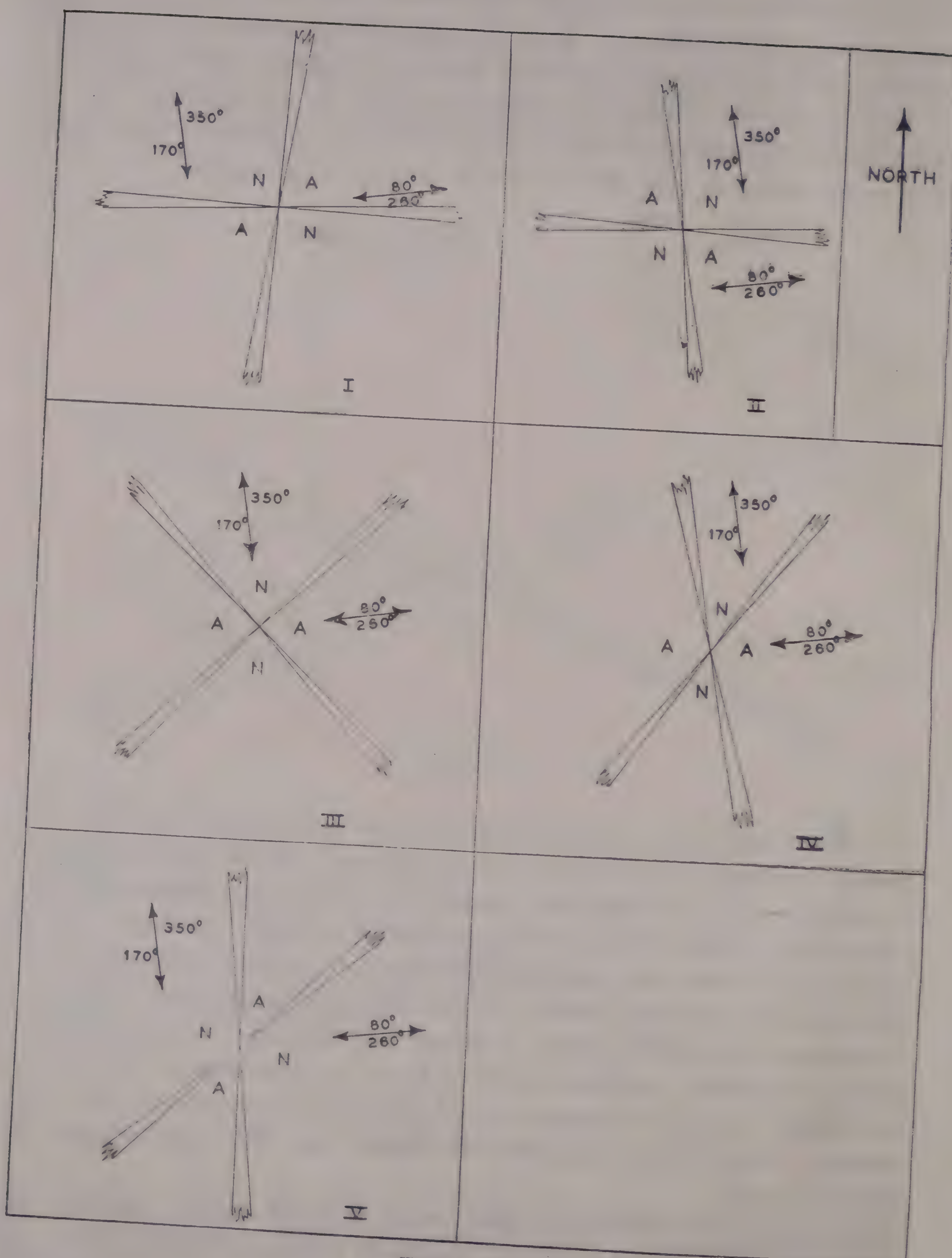

350°
170°
N
A
80°
260°
A
N
I
350°
170°
A
N
N
A
80°
260°
II
NORTH
350°
170°
N
A
A
80°
260°
N
III
350°
170°
N
A
A
80°
260°
N
IV
350°
170°
A
N
80°
260°
N
A
V

FIGURE 20.

figure 21. In this case a fade results on either bisector heading for the N quadrant. Actually, however, this fade or build would be so slow under the condition illustrated as to be unnoticeable unless the heading were flown for a long time, and as mentioned above a 90° turn should be made and the build or fade rechecked. If fading, turn 180° and continue as long as the signal strength or the back-

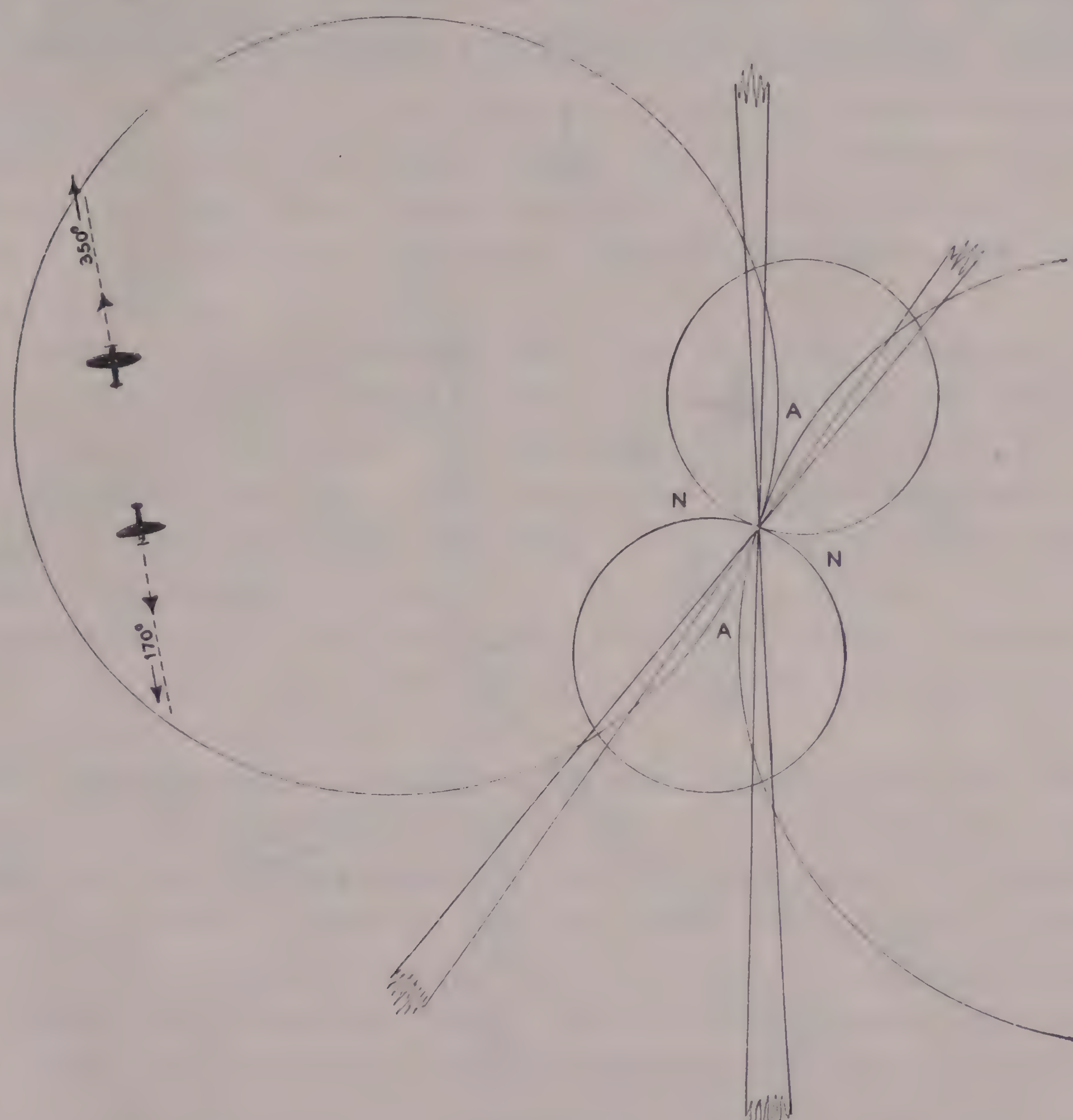


FIGURE 21.

ground, of any, is definitely increasing. If after a half hour or more of flight the signal strength again starts to decrease (without a definite and steady build in background), another 90° turn should be made and the fade again checked. Again, if fading, turn 180° and continue as long as the signal strength or background is definitely increasing. Simply stated, the system consists merely of flying into constantly increasing signal strength, turning 90° whenever necessary to accomplish it, until a beam is intercepted.

(3) Figure 22 illustrates the effect of drift on this system. Starting at (X) the pilot elects to adopt the 170° heading (because it was nearest to the heading he happened to have when the radio was tuned in). Holding this heading for several minutes he hears a slow fade in signal strength. (While he is not getting actually farther from the station he is going away from the center of the field of greatest signal strength.) So he turns 180° and flies the 350° heading. Unknown to him, there is a strong drift away from the

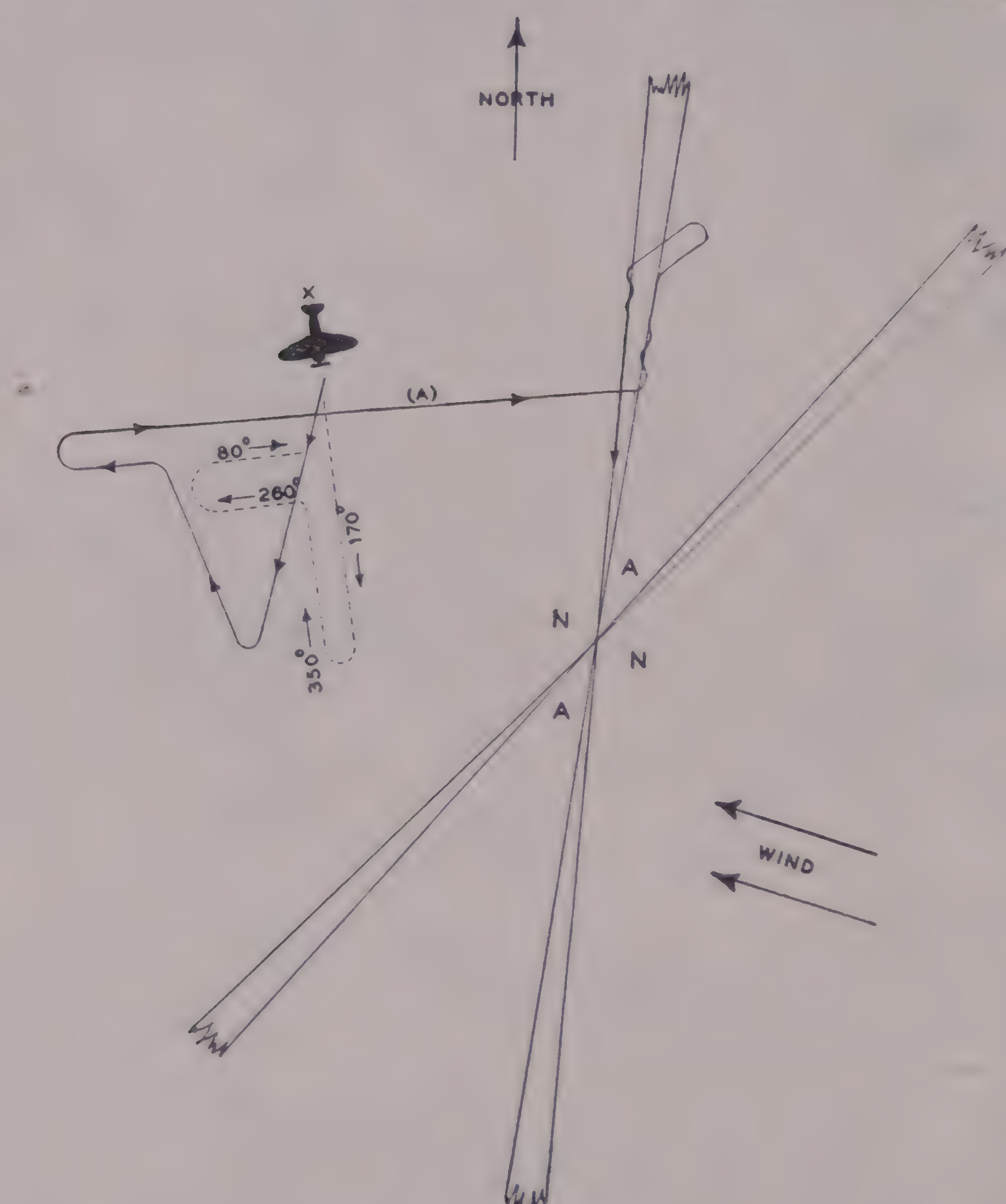


FIGURE 22.

station. The dotted line indicates his headings and what would have been his track in still air. The solid line shows his actual track as a result of the drift. On this new heading, although slowly approaching the stronger field of strength, he is definitely getting farther from the station and again gets a fade. The pilot then turns 90° to the left to a heading of 260°. He gets a rapid fade this time as he is going nearly straight away from the station and is pushed along by the tail wind. This is definite evidence, and the pilot turns 180° to the heading of 80° and holds it. The build is

slow but continuous so the pilot continues on the heading of 80°. At point (A) the volume ceases to increase and starts to fade slowly but the pilot remembers the rule about turning up the volume and checking for a background. There is a background so he continues to hold the heading and notes that while the volume continues to decrease slightly the background is steadily building, indicating that he is approaching a beam.

(4) The heading is held until across the beam, and on the first opposite off-course signal the pilot turns left and brackets the beam in the customary approved manner. He then rechecks the fade, finds he is going away from the station, does a procedure turn-around, rebrackets the right hand edge of the beam, and follows it to the station.

c. Advantages.—It provides the pilot with an emergency procedure in the event his map is lost or he has drifted over territory not covered by the maps. It will work in the majority of cases.

d. Disadvantages.—In most cases, the method requires much longer to work than other methods. It will not work in territory where false fading is prevalent. It requires extremely accurate judgment of signal strength on the part of the pilot. Though the method should be regarded only as an emergency system, it should be mastered, nevertheless.

36. Multistation system.—*a.* While circumstances are not always such that this system can be used, in most instances it will supply considerable information and in many cases will definitely place the position within a very few miles. It consists of tuning the station it is desired to approach and noting the signal received, and then tuning various selected surrounding stations and noting the signals received from them. A set of conditions is frequently set up under which the ship could only be in a certain area.

b. (See fig. 23.) Starting at (X) (but not knowing where he is) the pilot tunes in the station he wishes to fly to (marked #1). He receives an N quadrant signal. He also hears a background but has no way of knowing which of the four beams he is adjacent to. Looking at his map he notes that a beam from the station marked #2 lays practically over the station he is working on. He tunes in station #2 and hears an N with strong background. This definitely places him in the north N of station #1, as had he been in the south N he would have heard an A from #2. He now knows he is in the north N and near either the northwest or the northeast leg but does not know which. Checking his map he

notes that another station (marked #3) has one beam which cuts through the north N of his station so he tunes in that station. He receives an A with a strong background. This definitely places him somewhere within the dotted circle and the orientating was accomplished in the few minutes it took to tune in two extra stations. Knowing which beam he is close to he heads toward it. brackets it down, and follows the right hand edge to the station.

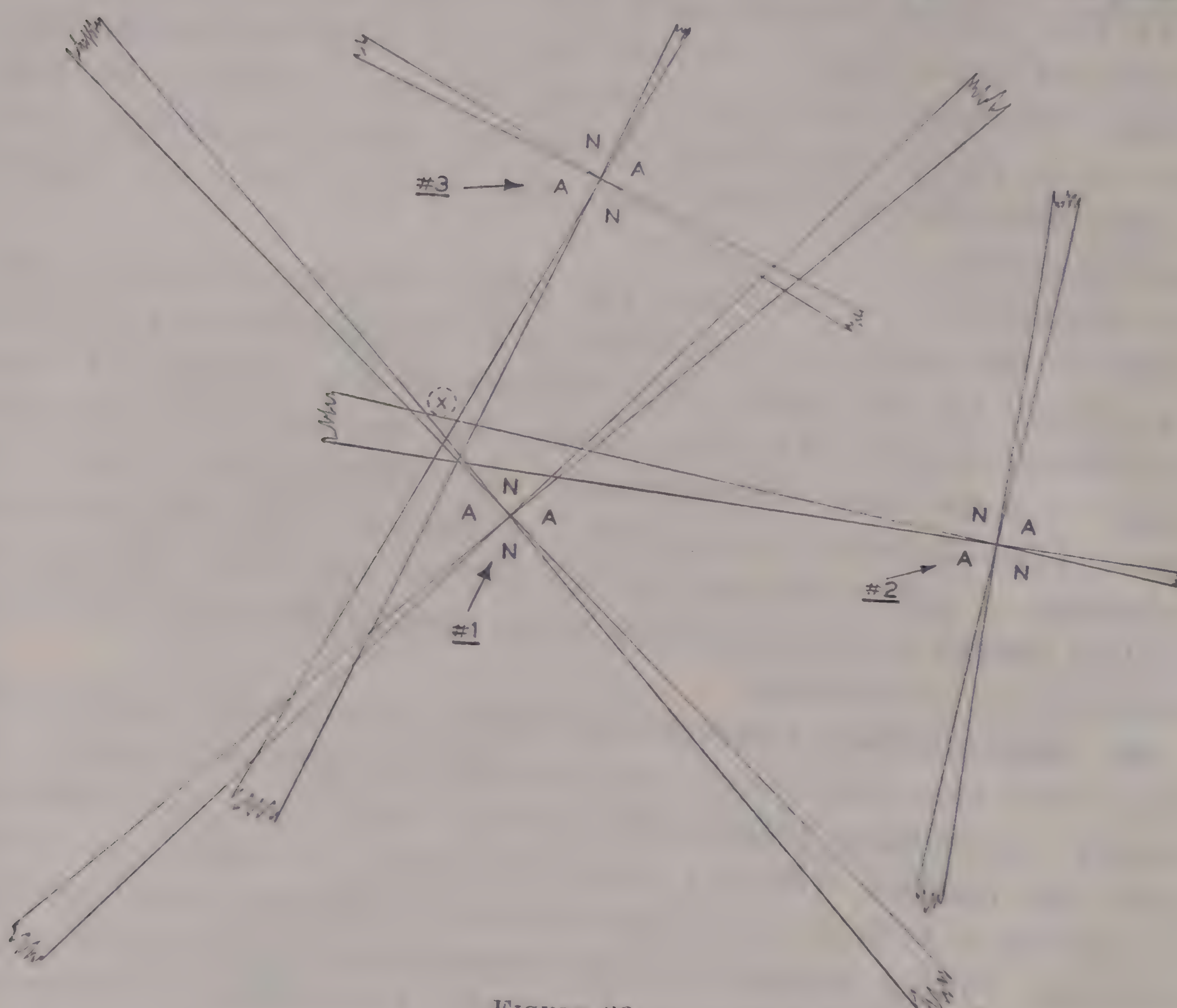


FIGURE 23.

37. Lost on beam system.—*a. General.*—When the radio is turned on it occasionally happens that the ship is on-course, already on one of the four beams. This is somewhat disconcerting, and unless the pilot is already armed with a suitable method he will probably feel that he must somehow get away from the beam in order that he may find it again, and in so doing waste considerable valuable time. Orientation consists of three steps; find a beam, identify it, and follow it to the station. If already on a beam when the radio is turned on there remains only to identify it and follow it in. There are two methods—one is an adaptation of the fade-out and the other of the 90° system.

(1) *Lost on beam fade-out.*—On tuning in the radio and hearing a solid on-course, turn to the nearest bisector heading to the left.

It may be any one of the four. Hold this heading until the edge of the beam is reached. (If the edge is not reached in 3 or 4 minutes, turn 90° to the left to the next bisector heading and hold it). When the first off-course signal is heard start a standard rate turn to the left and bracket the beam in the approved manner. Turn the radio volume down and check for a fade or build-in signal strength. If the signal is fading do a procedure turn-around and continue to the station. Meanwhile, the beam is identified by the letter on the right, the increasing signal strength, and the general compass heading. (Remember, the compass heading means nothing without checking the fade or build.)

(2) *Lost on beam 90°* (good only on "square" stations).—On tuning in the radio and hearing the on-course signal, turn to the nearest one of the four bisector headings. On reaching the edge of the beam do a 90° turn to the right. This turn will bring the ship either back across the beam or take it deeper into the off-course. Whichever it does, considered with the bisector heading selected to run off the beam, will definitely identify the particular beam. (See fig. 24.) Say the bisector heading of northwest (315°) was selected,

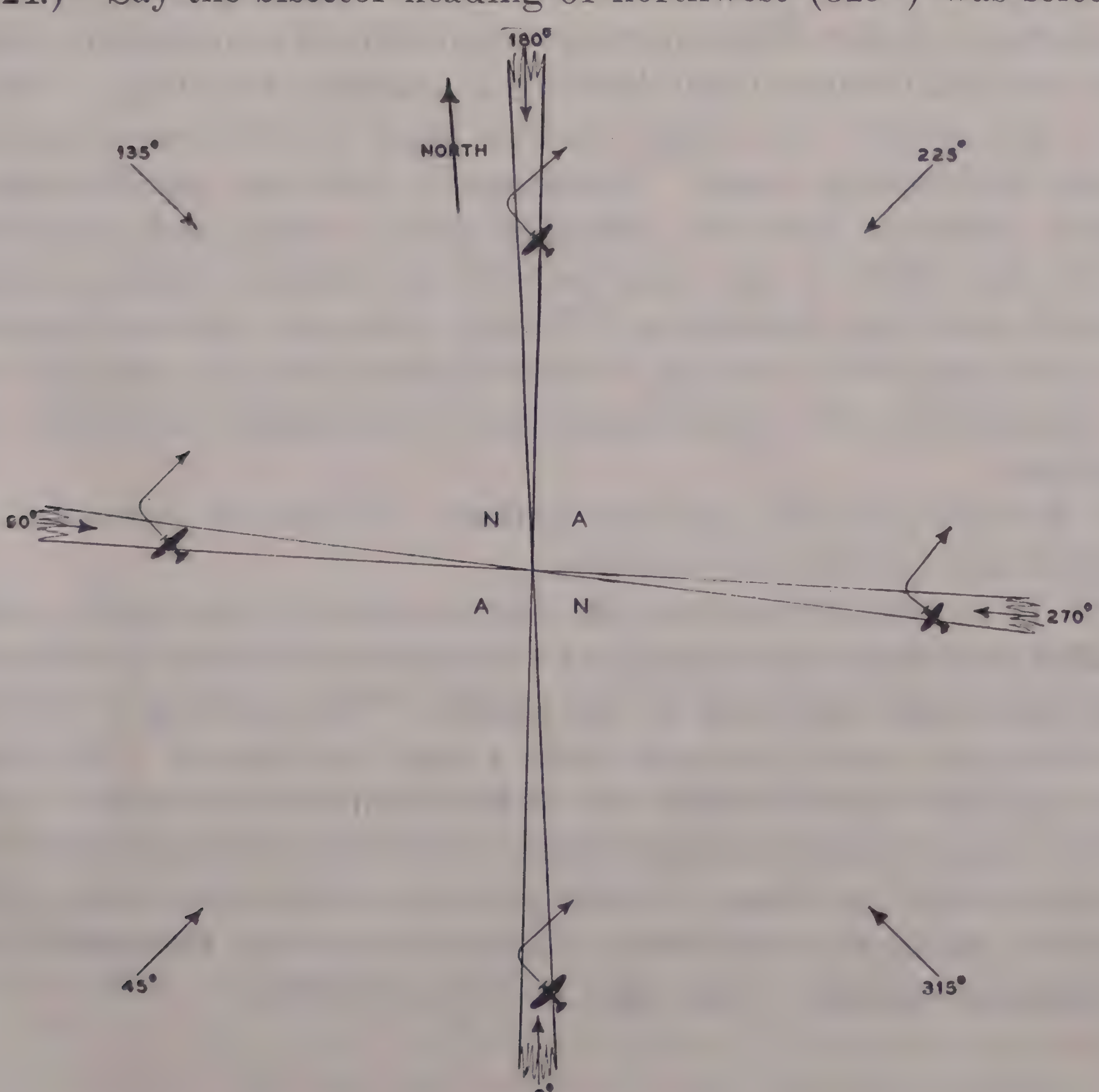


FIGURE 24.

turned to and held to the edge of the beam and the 90° right turn made. Note that the conditions are different for each beam. For example, if the ship went into an A and stayed in the A, the beam is identified as the east leg as, starting with the 315° heading, these conditions cannot exist on any of the other legs. If the ship went into an A then back into an N, the south leg is identified; if into an N and back into an A it has to be the north leg.

b. The 90° lost on beam method.—(1) *Advantages.*—The method is quick and positive where usable.

(2) *Disadvantages.*—It can be depended on only on a square station. It requires rapid and clear thinking on the part of the pilot.

c. Fade-out lost on beam method.—(1) *Advantages.*—The method will work on any station except where false fades are prevalent. It takes advantage of habits already formed and used in the fade-out system and in beam bracketing and so is easy to remember and nearly automatic.

(2) *Disadvantages.*—It will not work where bad fading exists. It takes more time to work than the 90° method.

38. Close-in procedure.—*a. General.*—When in close proximity to the range station it is sometimes impossible to complete an orientation method, because while holding a heading or making a turn to prove the identity of a beam, another beam will be crossed and confusing information result. Consequently, when the rapid change of signals indicates that the station is close at hand, and an attempt proves that there is not room to work an ordinary system, another method should be resorted to. In fact, when one realizes that he is in the vicinity of the station, he knows where he is and does not need to orientate himself (since orientation is the business of finding one's position).

b. Methods.—There are two methods of close-in procedure, the parallel and the bisector methods.

(1) In the parallel method the ship is turned to the heading which parallels the outbound bearing of the beam on which it is desired to make the initial approach to the station. This heading is held and the changing signals ignored until a fade is obtained. The signal then received will tell which side of the beam the ship is on. A turn of 45° is then made toward the beam. This new heading is held until 45 seconds past the beam. A 180° turn away from the station is then made to get back to the beam. The beam is then bracketed down in the usual manner. (See figs. 25 (A) and (B).)

(2) The bisector method is similar except the initial heading is that of one of the average bisectors. This heading is held until a fade is received and then a 90° degree turn is made toward the desired leg. This heading is held until the beam is crossed and then the same procedure is followed as in the parallel method. (See fig. 25 (C).)

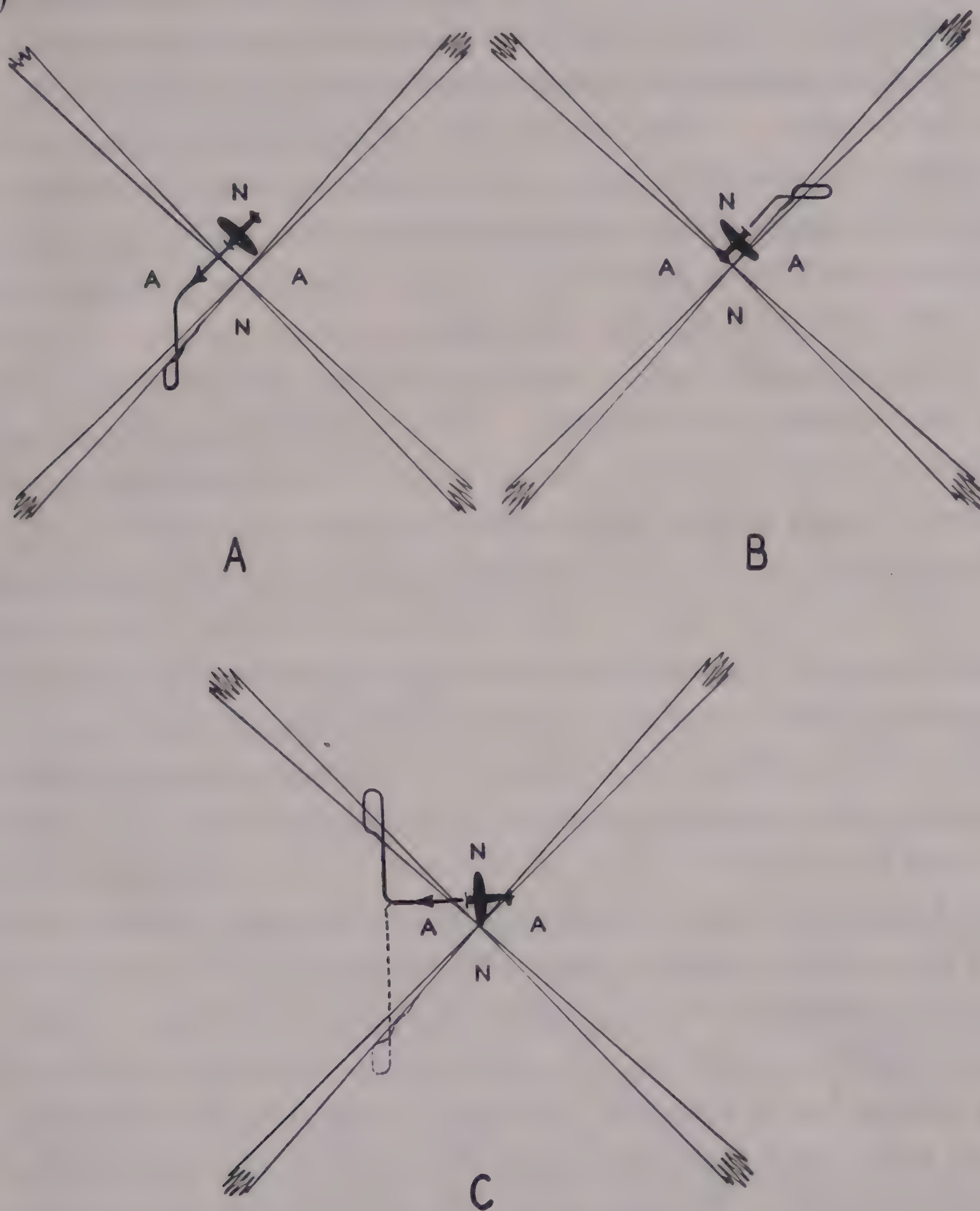


FIGURE 25.

c. Advantages.—Either method provides a quick, positive, and easy method of getting onto the desired beam when lost or confused near the station.

d. Disadvantages.—(1) *Parallel method.*—When working a station with two very narrow quadrants there is a possibility of a strong wind drifting the ship across the narrow quadrant. When the open quadrant signal is received the pilot cannot be sure which of the two quadrants he is in. This condition is, however, readily detected when the turn is made to get back to the beam. If the ship has drifted into the other quadrant the background will diminish rapidly.

(2) *Bisector method.*—This method can be relied upon only on a square station. It takes slightly longer than the parallel method.

39. Let-down and low approach.—*a. Procedure.*—(1) Letting down procedures and low approaches vary according to the terrain, obstructions, station pattern, etc. A sample should be selected to give the student a general idea of the means he is to use on most stations, and he should be cautioned that this particular procedure may not be the one that is actually used on the station he happens to be working on the trainer. The proper procedure can be obtained from the tower after the control area is entered, or the procedure may be studied beforehand from CAA publications. The sample procedure is designed merely to give the student practice in doing the mental gymnastics required in any let-down.

(2) The approach leg is usually the one diametrically opposed to the leg that crosses the airport. If the airport is not on a leg, then the approach leg is the one from which the least amount of turning is required to get to the field, after passing the cone.

b. Turning to get on the approach leg.—(1) On some patterns the station may be very close to the field, and letting down at safe vertical speeds may be impossible if straight line flight is attempted. In these special cases common sense dictates the proper procedure. In any case, surrounding obstructions, conditions around the field, station pattern plus common sense will point the way. For problems of this nature the airport must be drawn in on the chart to scale at a distance from the cone in keeping with recorder travel.

(2) The student comes over the station at the conclusion of his orientation problem at the initial approach altitude, reports in, and requests weather, traffic, and permission to make a low approach. While talking he is already turning to get on the approach leg and stops the turn on a heading that will attack the approach leg at an angle of about 45° This heading should be held only long enough to get to the beam. The number of seconds required to do this should be estimated, and if conversation with the tower exceeds the estimate, a turn should be made to a heading parallel to the approach leg and this heading held until the range signals are again received. If he gets permission to come in he slows down to gliding speed and proceeds out the approach leg for 3 minutes. The time is noted at the point when the student figures he is abreast of the station.

(3) At the end of 3 minutes (time depends on wind conditions) he does a procedure turn-around. Having established his drift while proceeding out the approach leg he can apply it when returning to the beam and slide on to it with very little bracketing. Since

the beam 3 minutes from the station is very narrow, the pilot should be content to stay in it rather than attempt to find its right-hand edge.

(4) Gliding to the final approach altitude should be started in time to reach this altitude several seconds before the station is crossed for the second time. The final approach altitude (minimum safe altitude) and the actual moment to begin the glide are dependent, of course, on the surrounding terrain and the initial altitude. No definite rules can be set down here because each station has its own peculiar problems.

c. Information required.—Before starting a problem involving a low approach the instructor should require the student to supply the following information:

(1) *Name of station to be worked.*

(*a*) Call letters.

(*b*) Field elevation.

(2) *Flight altitude.*

(*a*) To be worked at 500-foot level (2,500, 3,500, etc.).

(*b*) Upon identifying leg, student to attain proper altitude for that airway.

(3) *Time out the approach leg.*—This must not exceed 3 minutes unless permission is obtained beforehand (in case of head wind).

(4) *Final approach altitude.*

(5) *Vertical speed.*—Amount student figures he must maintain during final approach.

40. Selection of proper procedure.—*a.* The foregoing methods and systems are not really separate systems at all. They are merely the parts that form radio range orientation. There are basically only two ways to identify a radio beam: by a 90° turn or by the change in signal strength, or a combination of both.

b. The pilot must have a clear understanding, however, of exactly under what conditions the basic steps or their various combinations will work, and the conditions under which they will not work. The foregoing outline of systems is merely a step by step presentation of orientation procedure, broken down to show the proper combination of the basic elements as applied to specific situations. When the various steps and systems have been thoroughly mastered, the student will have a complete picture of range orientation and will no longer need a system or a variety of them. He will execute the maneuver that common sense dictates for the particular set of conditions; and will know enough about orientations so he will not be tempted to depend on some short-cut or cure-all procedure under conditions when it will not work.

c. Obviously, if such a pilot finds it necessary to orientate on a scissor station and in an open quadrant, he will identify the sector by a fade or build; and after reaching a leg will identify it by again checking the fade or build. If he is in a squeezed sector of such a station he will identify the sector by signal strength, but he knows that after this is done the leg can be quickly identified by a 90° turn; or he will head directly toward a chosen leg if he desires to approach the station on that particular leg.

d. Stated briefly, after the pilot has mastered the preceding outline of orientation he will know enough about the entire subject and the limitations so that all he needs to do is to exercise common sense.

CHAPTER 3

ADVANCED COURSE IN TRAINER

SECTION I

OPERATION

41. General.—*a.* Radio range orientation can be taught more thoroughly and in less time in the Link trainer than in actual flight. Several factors contribute to this. Signals may be (and should be) exaggerated during the early stages of instruction. The "flight" may be momentarily "suspended" at any time and any confused point in the problem straightened out and the problem then continued (obviously impossible in actual flight). Perfectly clear signals and interphone are available at all times. On the chart an accurate tracing of the entire problem is available for later discussion and analysis, showing beyond room for doubt or argument just where the student under the hood made his mistakes.

b. All of the preceding systems and procedures may be taught and practiced until, when finally using them in the air, the pilot knows exactly what he is to do and precisely how to do it. This practice can and should include such peculiarities of radio ranges as bent beams, swinging beams, dog legs, etc. It should be borne in mind that training received in the trainer will be good only as long as the instruction is good and the signals properly simulated. The various exercises and methods should be taught in the order in which they are outlined in the section dealing with orientation methods. Inasmuch as beam bracketing must be used in all subsequent exercises it should be taught first. Before starting radio, however, the instructor should make sure the student is familiar with range signals. To check him on this a radio range chart should be drawn. With the ear-

phones on, the student should run his finger slowly back and forth across various parts of the chart while the instructor sends him the proper radio range signals for the position of his finger relative

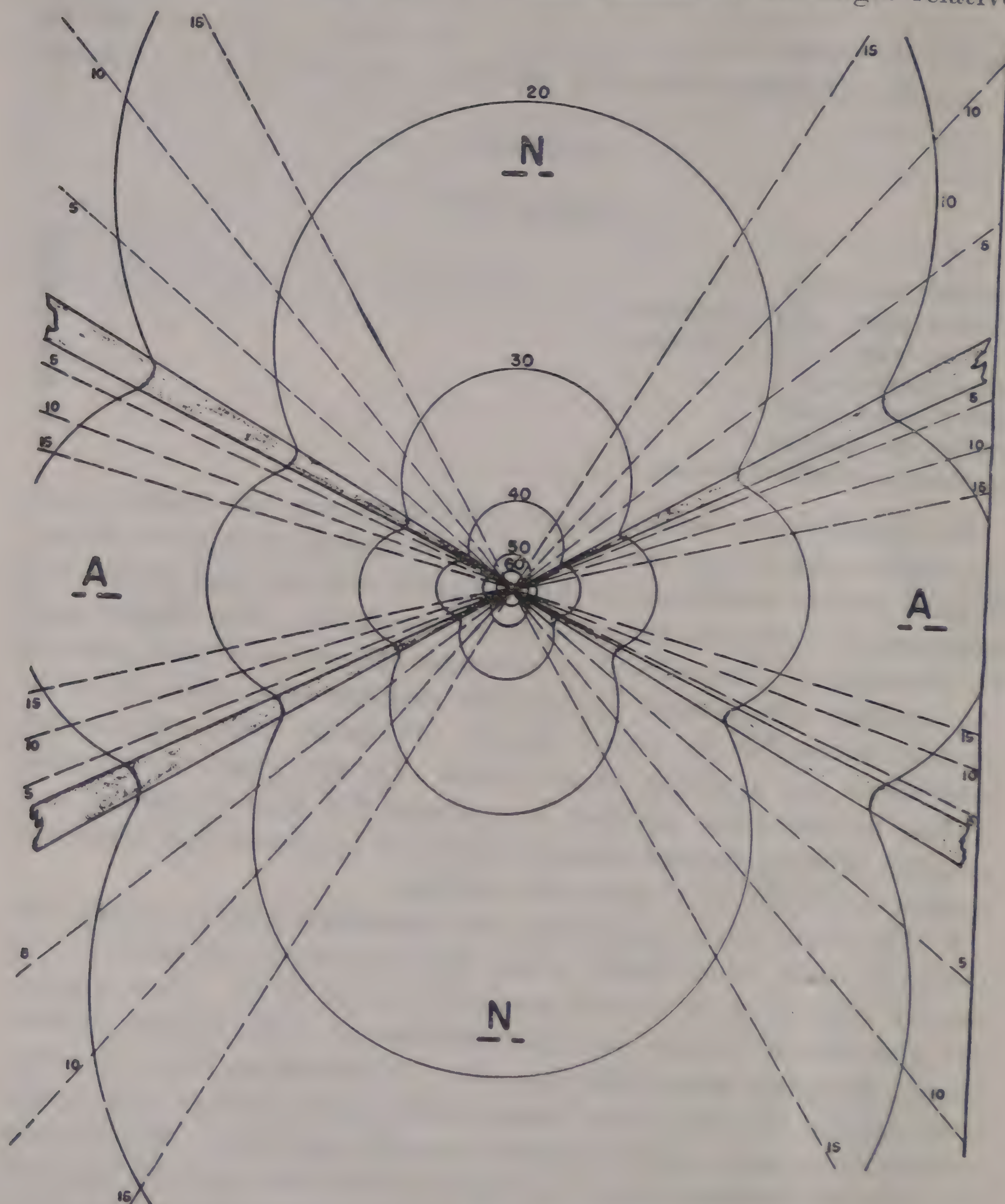


FIGURE 26

to the beams. When it is apparent that the student knows what to expect from the range signals, have him look away from the chart, run his fingers across the chart, and explain from the sound of the signals the position of his finger. When it is perfectly clear that

the student understands the signals, he is then ready to get into the trainer and start practice on beam bracketing.

42. Trainer radio range operation.—*a.* Figures 26, 27, and 28 are typical lay-outs of radio range stations except that approximate lines of equal signal strength have been drawn in. It is recom-

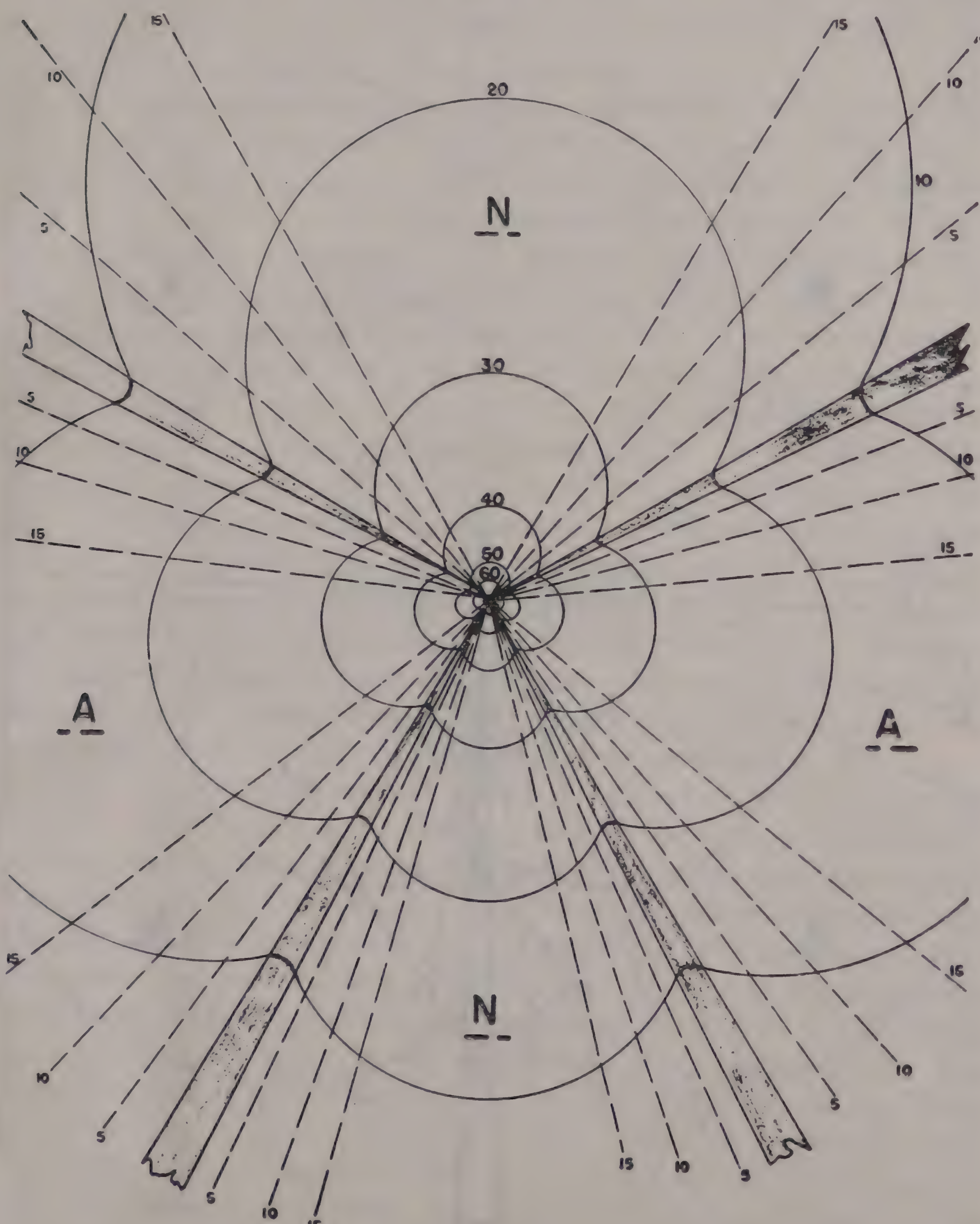


FIGURE 27.

mended that 24-inch square copies of the sheets be prepared and used for orientation problems. Note that space is provided for the student's name and other data pertaining to the problem. These per-

manent graphs should be filed away and can be referred to at any time as a record of the progress and ability of the student.

b. These three figures show three types of radio range stations: the square station, scissor, and crowfoot. Since signal strength patterns vary widely with the different types, the lines of equal strength

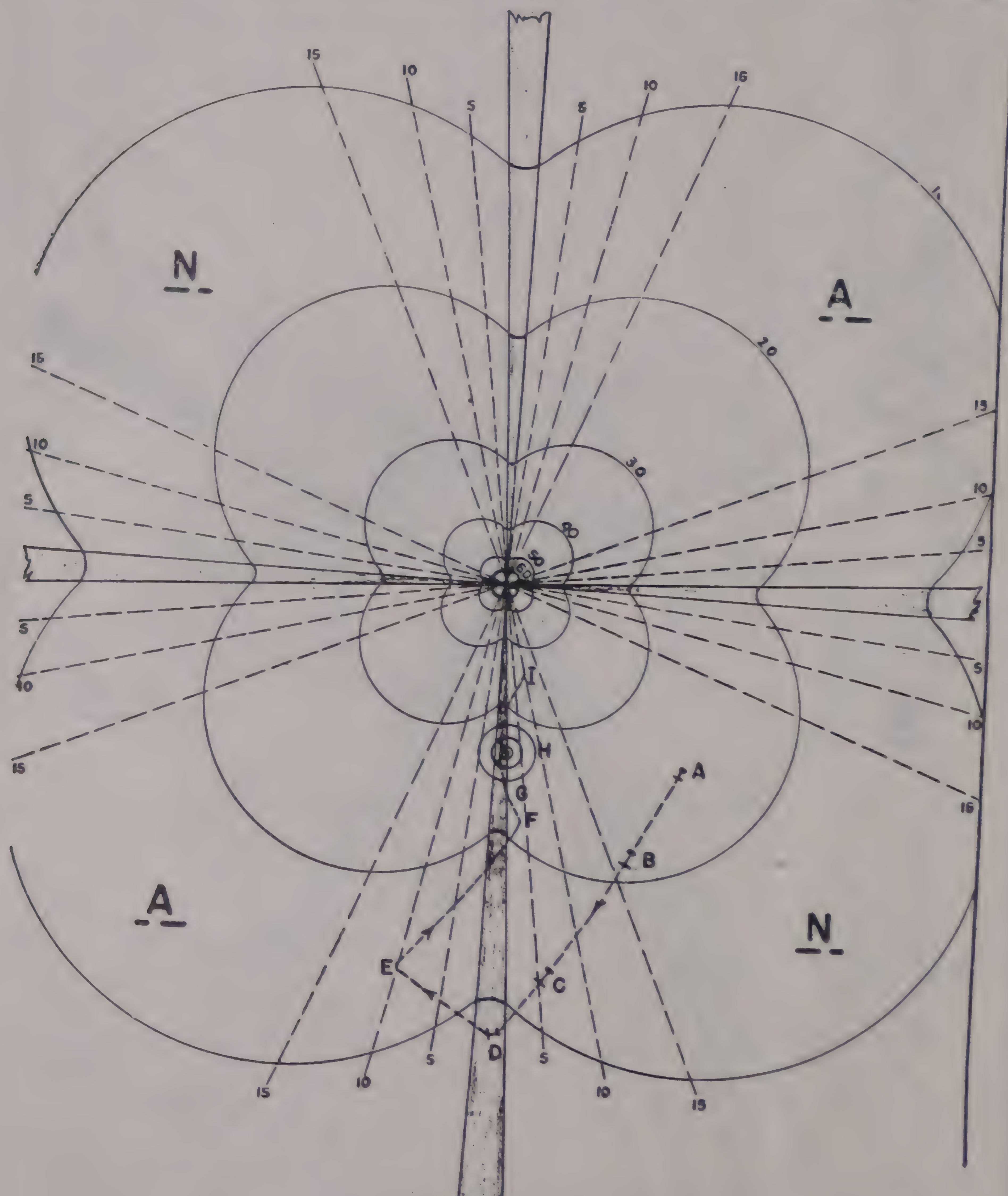


FIGURE 28.

are drawn in and numbered as an aid to the instructor in giving correct signals. It will be noted on these charts that the signal strength lines are increasingly closer together as the station is approached. It will

also be noted that the line nearest the station is numbered 60. From this point to the station, the increase in signal strength is so rapid that lines representing 70, 80, and 90 would be crowded and confusing. These lines (70–80–90) should be imagined and the volume control used accordingly. If the volume control, which is also numbered from 0 to 100, is made to agree at all times with the numbered lines on the chart, the fading and building of signal strength will automatically approximate actual range signals.

c. The shaded portion of the beam is always an on-course signal and requires the setting of the A and N control at zero. This is the control located at the extreme right on the radio chassis. The dashed lines 5, 10, and 15 on the charts represent the amount to set this control off-course according to the position of the recorder inking wheel. For example, referring to the chart (fig. 28) the student is flying southeast from the theoretical position A. The volume should be set at 25 and the A and N beam shift control as far off-course in the N quadrant as possible, which is 15. The student flies southeast for 2 or 3 minutes. This brings him to position B. The volume should be changed gradually to approximately 22 during the change of position. The student continues flying southeast, gradually reaching position C. During this time, the volume changes gradually to 15, and the course beam control is slowly brought from 15 through 10 to 5. At position D, the course beam is at 10 and the volume at 15. Heading northeast the student returns to the beam. At point F he has passed through the on-course and should be given a slight N—about 3 on the beam control, which again is changed to 0 or on-course at G.

d. At this point the marker beacon is turned on with the beacon set at 0. This volume is rapidly increased to the maximum setting of 100 and then fades out again, indicating the plane has passed over the marker at position H. At this point, the beam control is still zero and the volume is nearly 30. At position I, it will be noted that the student has run off-course slightly, and the control setting should have been gradually and smoothly changed to 35 and 5. Continue the proper signals in the same manner throughout the problem. The cone of silence at the station is obtained by turning the volume down and returning it again to full volume in from 1 to 10 seconds' time depending on the student's altitude. In fading out the signal to simulate the cone, the signals will sound more natural if the the rate of fade is in proportion to the length of the time of the cone of silence. A small cone requires a quick fade.

Second:	Altitude (feet)
1	500
2	1,000
3	2,000
4	3,000

Second—Continued.	Altitude (feet)
4	4,000
5	5,000
6	6,000
7	7,000

e. Attention is called to the fact that the signals at a given distance from the station are considerably louder when entirely off-course, midway between two beams, than when actually on the beam. Bent beams, multiple courses, etc., may be drawn on the map and simulated by manipulation of the controls. At intervals, a standard weather broadcast should be made. The student should be required to "report in" and all control tower routine should be practiced. The instructor must remember that the beam is very narrow close to the station. When the inking wheel is within a minute or so of the station, a solid steady on-course should not be given unless the wheel is exactly centered on the line which represents the beam, and is pointed exactly toward the station; giving too wide an on-course near the station is a fault found in many instructors.

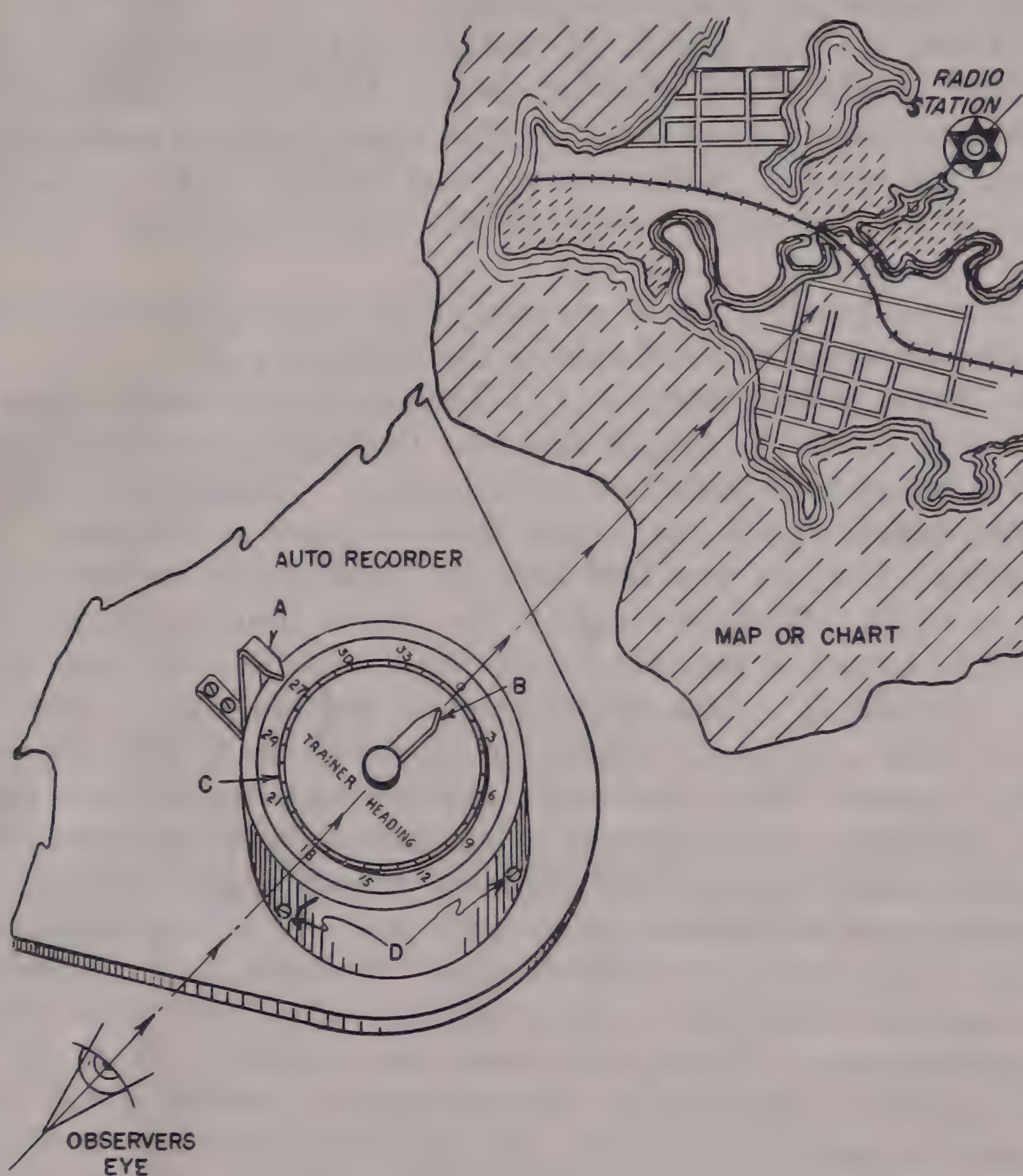
f. Operation of the desk equipment requires real skill and practice on the part of the trainer instructor. He should avoid steering the student to the correct heading with signal changes that would not occur in the air. An example of this is frequently noticed in instructors who react to the slightest turn to the inking wheel before it has had time to move actually closer to or farther from the beam edge. While such tricks may result in a better looking track on the trainer chart, the student will not have profited by it. The instructor should bear in mind at all times that he is not supposed to teach his students to fly the trainer but to prepare them to fly airplanes on instruments.

43. Trainer radio compass operation.—(See sec. I, ch. 4.) *a*. With the student in the trainer and ready and the flight log moving across the map, turn on the radio compass switch on the small control box alongside the radio in the desk drawer.

(1) Rotate the round, movable scale on top of the recorder until the zero of this scale is in line with the spot representing the radio station on the map (fig. 29). Turn the radio compass (RC) volume control (on the small control box) about one-third on.

(2) When the student turns the trainer until the inking wheel is moving directly toward the radio station on the map, the pointer in the cockpit will be centered on zero. The instructor must continue to keep the 0 of the movable scale (fig. 29) pointed toward the radio station.

(3) As the recorder approaches the station, the instructor should gradually increase the radio compass volume. When the inking wheel gets close to the station, the instructor should move the round scale very slightly. As the student turns the trainer to center the



OPERATION OF RADIO COMPASS CONTROL
FOR
A RADIO COMPASS PROBLEM.
FIGURE 29.

left-right pointer again, the instructor should turn the scale slightly in the opposite direction. This causes the radio compass pointer to become difficult to manage and simulates the ultra sensitivity found near the station in actual flight. The instructor should cause this unruly tendency of the needle to become increasingly worse until the inking wheel passes over the station. At this point the rotating

scale must be turned 180° in order to keep the 0 pointed toward the station. Turning the scale 180° also has the desired effect of causing the needle to give opposite indications. When the student again turns toward the station, the needle will be automatically corrected to again give proper indications.

b. There are two schools of thought as to which direction the indicator should swing when off-course. One prefers indication as in the turn indicator and the other, just opposite, so the needle points toward the station. Either system may be used in the trainer by means of the reversing switch on the small control box, but the latter is preferred.

c. During practice, all movements of the rotating scale should be smooth and steady to avoid causing the needle to jerk.

44. Beam bracketing.—*a*. (1) The purely mechanical method of bracketing should be taught first and thoroughly mastered by the student before he is permitted to "anticipate." Simply draw several parallel beams on any convenient sheet of paper of the proper size for filing. For the first half hour the beam should be about 9/16 inch in width. Without regard to the trainer heading, the recorder should be turned so that the inking wheel will cross the beam at an angle of about 45°. (See fig. 30, position #1, beam #1.) The first two or three attempts at bracketing should be made with this easy angle of attack. When the student demonstrates that he has a fairly clear conception of the process of mechanical beam bracketing, the recorder should be so set that the more difficult angles of attack are employed, such as position #3 on beam #1. As soon as the student is able to cope with these difficult angles of attack, he should be put on a narrower beam such as beam #2, figure 30. This beam should be approximately ¼ inch wide, using the standard 1 R. P. M. recorder motors. The recorder should then be set so that it will cross the beam at approximately 90°. The first right-hand turn to get out of the beam following the first left-hand turn should carry the student back across the beam into the original off-course signal. He will then often fail to recognize that it is the wrong signal and that he is on the wrong side of the beam and will start turning left. This is a tendency which will be found in nearly all students and should be corrected in the early stages of beam bracketing practice.

(2) As soon as the student can successfully bracket a narrow beam and is able to recognize, but not become confused by, the signal on the left, his practice should be done on beam #3, figure 30. Practice on this beam should include not only beam bracketing but also following the right-hand edge of the beam to and over the station A.

(3) Since getting onto a beam and following it to the station is the goal of most orientation work, it is important that the foregoing exercises be mastered before attempting to progress to the more interesting orientation problems.

(4) During all this beam bracketing practice the off-course signal should be clear, loud, and distinct. Do not be afraid to exaggerate greatly the rate of signal change in the off-course zone. After the

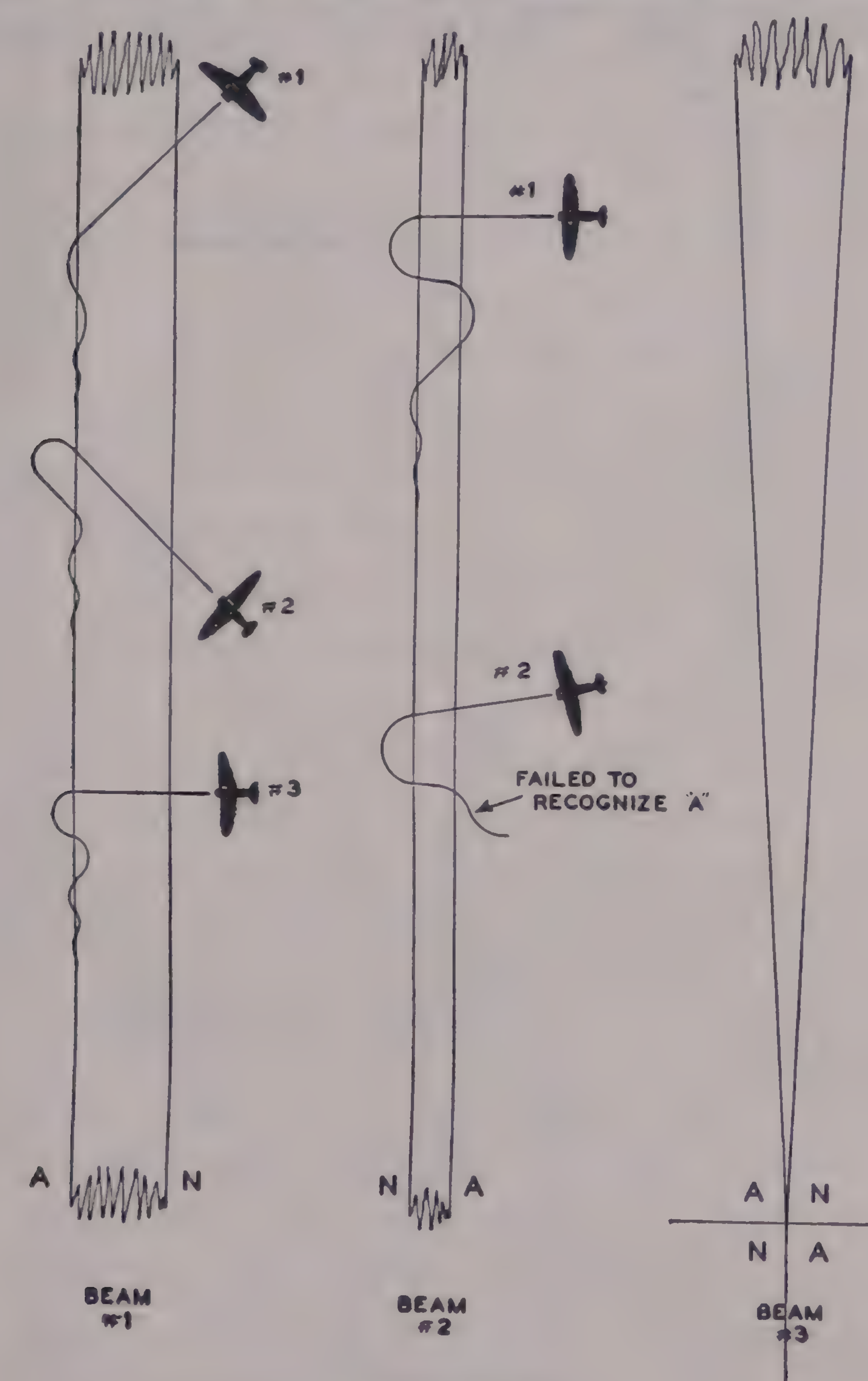
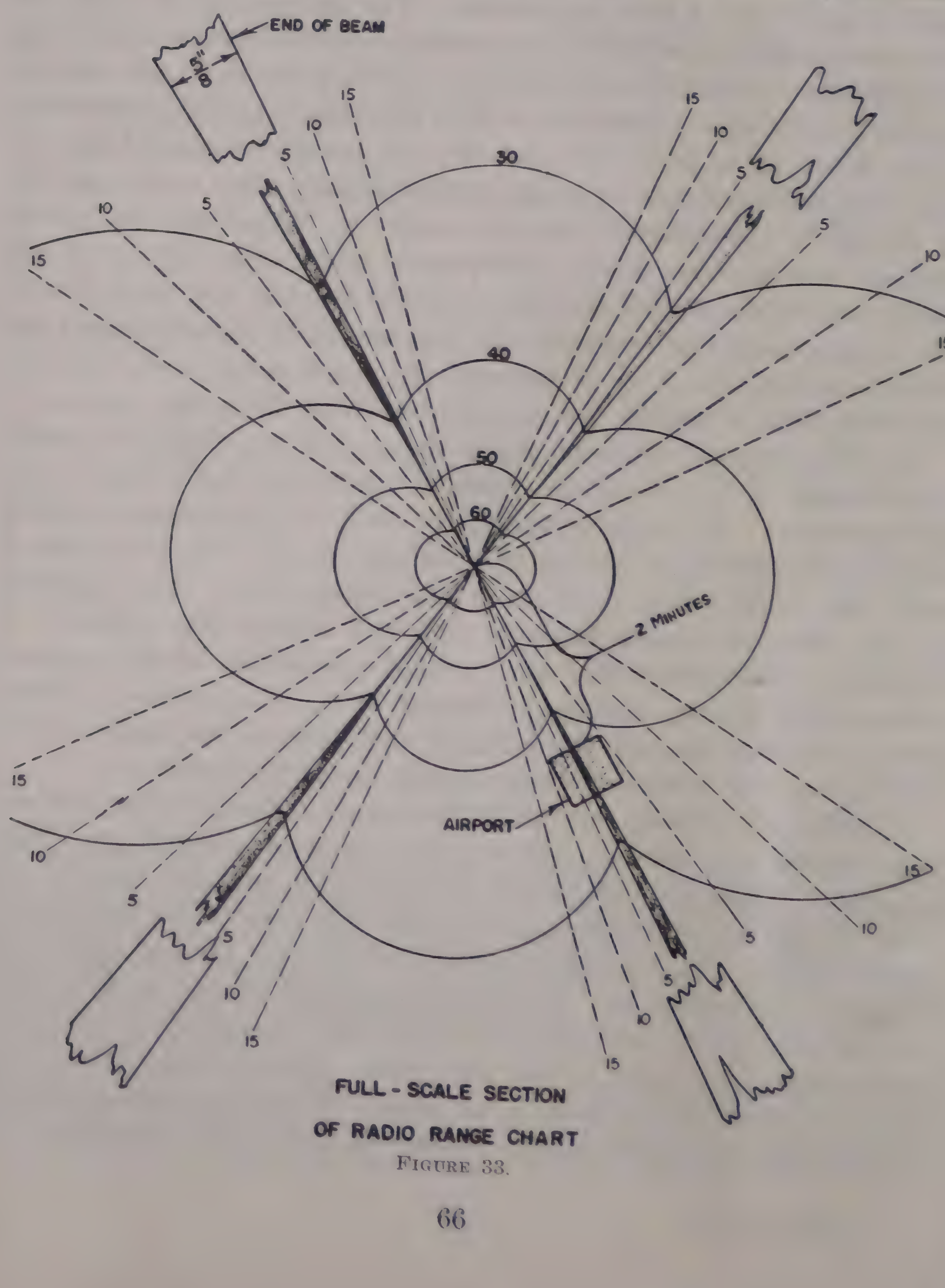


FIGURE 30.

student knows what he is trying to do there is plenty of time to cultivate his ability to detect faint or slight signal changes. It is also necessary during these early stages of radio practice to "lead" the inking wheel. The point on the wheel which should be used as a reference in handling the beam ship control should be the forward on third mark. (See figs. 31 and 32.) This leading is very necessary in the early stages of radio practice to allow for the mental lag of the student working under the hood. Later on in the course as his ability increases and his perceptions sharpen, the signal change may gradually be made to simulate conditions as actually heard in

45. How to make charts.—*a.* Radio range charts may be printed in quantities or drawn by hand on plain paper; white or light-colored wrapping paper will do.

(1) Charts should be 24 to 36 inches square. In laying them out, a compass rose should be drawn or stamped in the middle of the blank chart. The courses of any station may then be drawn in on their proper bearings. The intersection of these courses will be at the center of the compass rose. For the first inch or inch and a half out from the station, the courses or beams should be *only the width of a fine pencil line.* (See fig. 33.) From this point on out, the beams



FULL-SCALE SECTION
OF RADIO RANGE CHART
FIGURE 33.

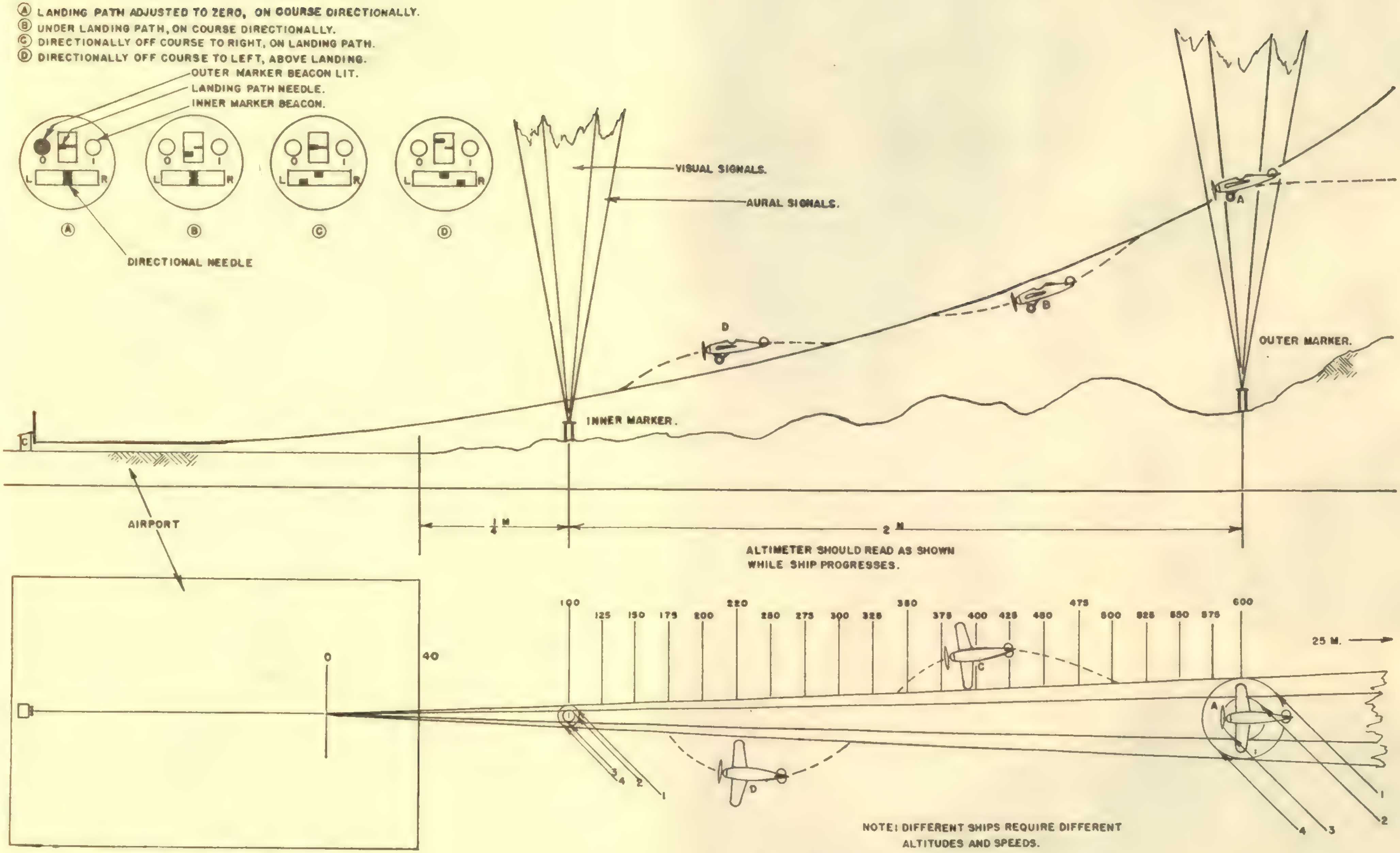

Ⓐ LANDING PATH ADJUSTED TO ZERO, ON COURSE DIRECTIONALLY.
Ⓑ UNDER LANDING PATH, ON COURSE DIRECTIONALLY.
Ⓒ DIRECTIONALLY OFF COURSE TO RIGHT, ON LANDING PATH.
Ⓓ DIRECTIONALLY OFF COURSE TO LEFT, ABOVE LANDING.
OUTER MARKER BEACON LIT.
LANDING PATH NEEDLE.
INNER MARKER BEACON.
DIRECTIONAL NEEDLE
VISUAL SIGNALS.
AURAL SIGNALS.
INNER MARKER.
OUTER MARKER.
AIRPORT
ALTIMETER SHOULD READ AS SHOWN
WHILE SHIP PROGRESSES.
100
125
150
175
200
220
250
275
300
325
350
375
400
425
450
475
500
525
550
575
600
25 M.
0
40
NOTE: DIFFERENT SHIPS REQUIRE DIFFERENT
ALTITUDES AND SPEEDS.

Figure 34.

5:00 P.M. BROADCAST

WWX		45		8		49/45	10	9.70
WAB		25		6		46/42	18	9.59
WUX	I	10		3	H	47/45	14	9.58
WAC	I	5		1	H+ R+	55/55	10	9.48
WAX		20		5		50/46	10	9.46

5:15 P.M. BROADCAST

WWW				10		50/40	10	9.58
WAC	I	5		1	H+ R+	55/55	10	9.48
WUX	I	10		3	H	47/45	14	9.58
WXX		80		6		45/38	8	9.58

6:00 P.M. BROADCAST

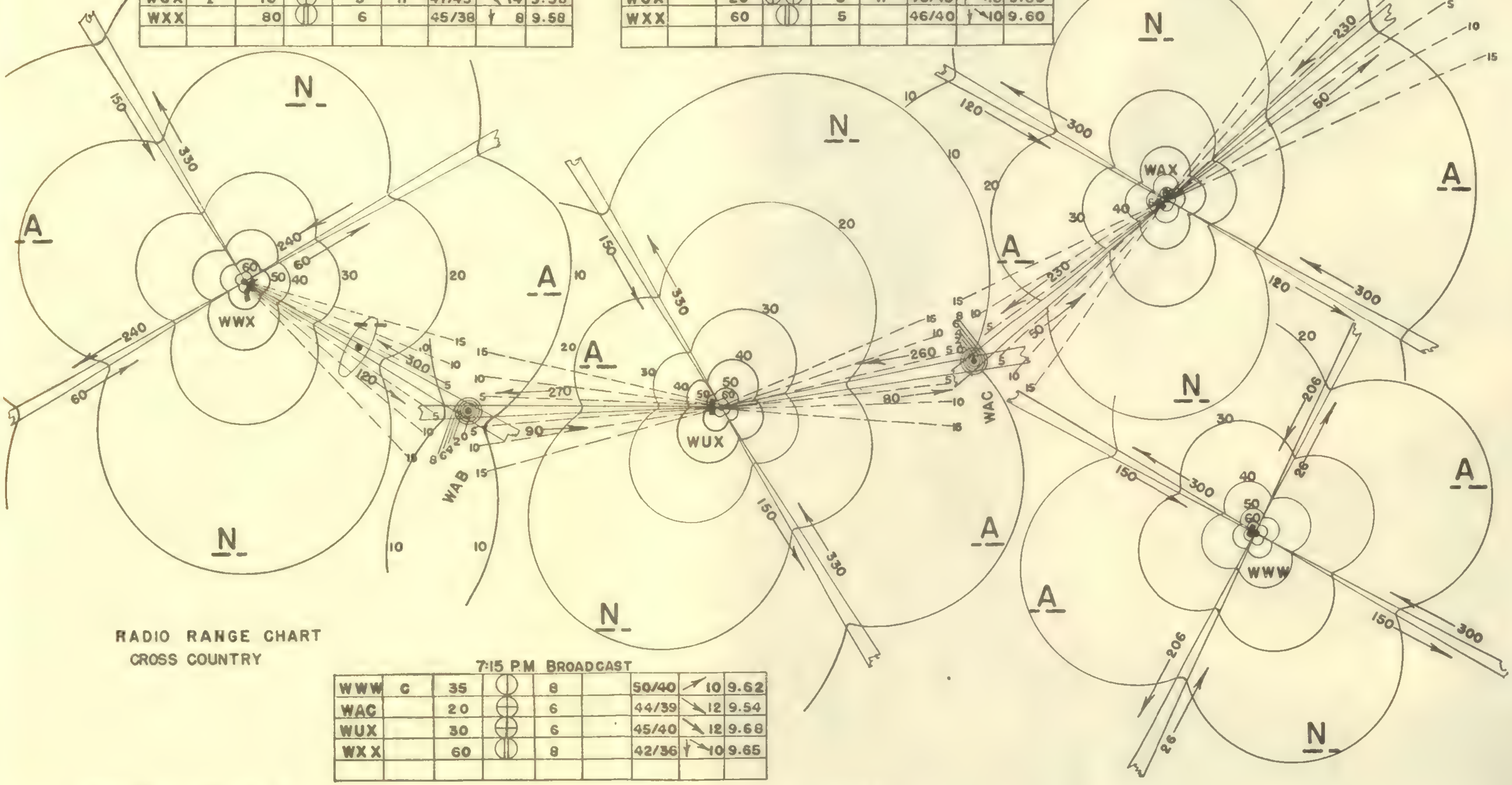
WWX	C	60		10		48/42	10	9.74
WAB		35		4		47/43	14	9.66
WUX		20	5/	5	H−	45/43	18	9.63
WAC	I	10		3	H+	44/42	18	9.50
WAX	X	5	1/	2	R+	46/46	25	9.41

6:15 P.M. BROADCAST

WWW	C	25		10		50/42	15	9.60
WAC	I	10		3	H+	44/42	18	9.50
WUX		20		5	H−	45/43	18	9.63
WXX		60		5		46/40	10	9.60

7:00 P.M. BROADCAST

WWX		65		12		48/40	8	9.79
WAB		40		6		48/43	10	9.70
WUX		30		6		45/40	12	9.68
WAC		20		6		44/39	12	9.54
WAX	I	10		4	R+	33/38	14	9.50



7:15 P.M. BROADCAST

WWW	C	35		8		50/40	10	9.62
WAC		20		6		44/39	12	9.54
WUX		30		6		45/40	12	9.68
WXX		60		8		42/36	10	9.65

FIGURE 35.

should be about 3° wide. "Twilight" or bisignal zone lines and lines of equal signal strength should then be drawn in as shown on the sample charts (figs. 26, 27, and 28). Obstructions and elevations may be shown if desired, but the fewer lines the chart has the less possibility there will be of the instructor becoming confused and giving the wrong signals.

(2) Large A's and N's should be stamped or drawn in the proper quadrants and the average bisectors added if desired. The airport should be drawn in to scale and at the proper distance from the station. The scale is determined by the recorder speed. For example, a given station is 4 miles from the field; gliding speed, 120 m. p. h.; it requires 2 minutes for 4 miles at 120 m. p. h.; in 2 minutes the standard recorder on 60-cycle current will travel 1¾ inches; therefore, in this case, the field on the chart should be 1¾ inches from the station.

(3) Various landing system charts may also be drawn with a little ingenuity and reference to figure 34.

b. When the student becomes proficient in the various methods of radio navigation, he should be given a cross-country problem. Figure 35 is suggested as a guide in laying out cross-country charts, which should be approximately 36 inches by 60 inches in size. The following routine is suggested:

(1) Require the student to study the course to be flown, to ascertain by weather reports the wind at the latitude he plans to fly, to observe the general conditions as if the flight were to be made in an airplane, and to plot his course for a predetermined cruising speed.

(2) He should carry a standard strip map in the cockpit along with such notes as will be of value to him as a pilot. However, these notes should be kept to a minimum to avoid confusing him.

(3) The student enters the cockpit, turns on the trainer, and checks the turn indicator for proper sensitivity. When the beam is turned on, it is assumed that an instrument take-off has been accomplished.

(4) Then require the student to circle the point of take-off until the desired altitude is reached; to note the exact time of departure from that point; to fly at a predetermined cruising speed; to make all turns by the count; to fly the beam edge at all times except when in the immediate vicinity of a station; to intersect all cones of silence and marker beacons along the route; and to notify the instructor by some prearranged signal of his desire to follow another beacon.

(5) Give the student cross winds and rough air at intervals along the route so as to make the problem as realistic as possible. At least one standard weather broadcast should be given near or at a cone of silence in each problem. In order to impress on the student the

necessity of using the beam as an aid to dead reckoning, the beam may be turned off for a short period. The student should be checked to see if he tunes to another beacon immediately, flies in a straight line, or wanders aimlessly about.

(6) At least two stations will have sufficient ceiling to make an instrument approach, but there will be a difference of 2° or 3° between the temperature and the dewpoint at one field, and a difference of 8° to 10° between the temperature and the dewpoint at the other. It will be considered disqualifying if an instrument approach is attempted at the former, providing the distance separating the two stations is not too great.

c. On completion of the above problem and all radio problems, ask the student to describe his movements from the time of take-off until the time of landing. The result of the problem should be filed.

NOTE.—It should be remembered that planes approaching a station have the right-of-way over departing planes. In order to establish a right-of-way, the incoming pilot flies the right hand edge of the beam until he is very close, within 5 miles of the station, when he flies the center of the beam to the cone of silence. Upon receiving the cone of silence he should veer to the right and fly parallel to the beam for at least 5 minutes before closing in on the beam edge. This maneuver gives the incoming plane the right-of-way and reduces the possibility of collision with the other aircraft.

46. Placing the recorder.—Placing the recorder on the chart properly is of the utmost importance since the trainer can draw a line on the chart in the proper direction only if the recorder heading agrees with the trainer heading. This is done by setting the recorder on the paper so that the north line is perpendicular to the side of the recorder farthest from the operator. (See fig. 36.) The inking wheel is then turned by means of the large recorder gears until it is traveling in the same direction on the chart as the trainer is headed. This may be verified by noting the pointer on the radio compass control, provided the radio compass control is properly set.

47. Application of drift to recorder.—*a.* It is essential that drift be applied in many orientation problems. The habit of teaching all orientation problems in "still" air (usually born of inertia on the part of the instructor) encourages the student to depend altogether too much on compass headings to identify a beam. This tendency is present in nearly all students and often can be cured only by the application of sufficient drift so that the information obtained from the compass alone will lead the student to believe he is on a different beam than where he actually is. This is particularly true of true fade-out problems. If the student is permitted to identify the beam from the compass heading (which often cannot be done in

actual flight) he will not have learned the system, and the first time he finds himself faced with the necessity to use it, if a considerable drift angle exists, he will become hopelessly lost and probably end by having to bail out. In this connection it is recommended that the instructor provide himself with actual winds aloft reports which show wind velocities that more than justify the drift angles he has applied. These are easy to acquire as such winds exist frequently.

b. The first step in the application of drift is to select the wird direction. If this is not done intelligently the point is lost and the drift might just as well if not better have been left off. Since true fade-out method will work in spite of drift, if done properly, it will be used to illustrate.

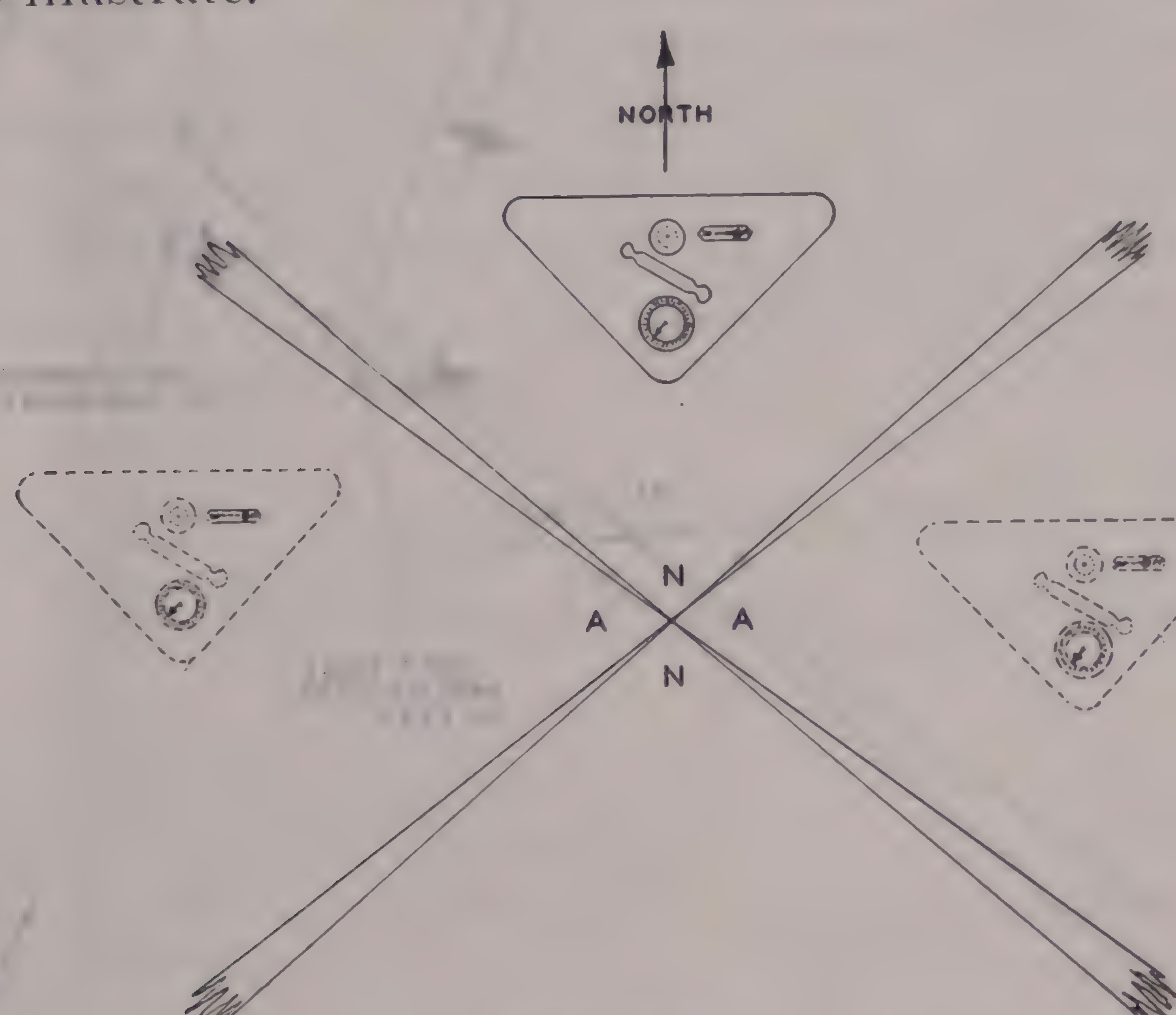


FIGURE 36.

c. Drift has its worst effect when working squeezed or scissor stations, therefore the Buffalo, N. Y., range is taken as an example. Suppose the recorder is to be placed in the north N quadrant. It should also be placed so that the student will intersect a certain leg. This should be the northeast leg so that when the student turns left and brackets the beam he will be going away from the station. (See fig. 37.) In this case the wind should be from the southeast, so that when the student has the beam edge bracketed and has established the compass heading necessary to stay on course, he will have a heading which more nearly approximates the inbound published bearing of the west leg. If he works the problem properly, rechecking his fade or build, he will have no difficulty in identifying the beam. However, if he attempts to identify it by the compass heading (as will often happen) he will assume himself to be on the

west leg and continue away from the station, eventually running out of signal or gas or both. Since this exact condition can and has occurred in actual flight, it will usually convince a student of the correct method when no amount of talk will do so.

d. The importance of the correct handling of the recorder and selection of wind direction cannot be overstressed. Due to mechanical limitations of the recorder, the most practical amount of drift is 30°. This is one "electrical notch" on the large recorder gears. Since the wind selected, as previously described, is practically a tail wind when approaching the beam it is not necessary to do anything

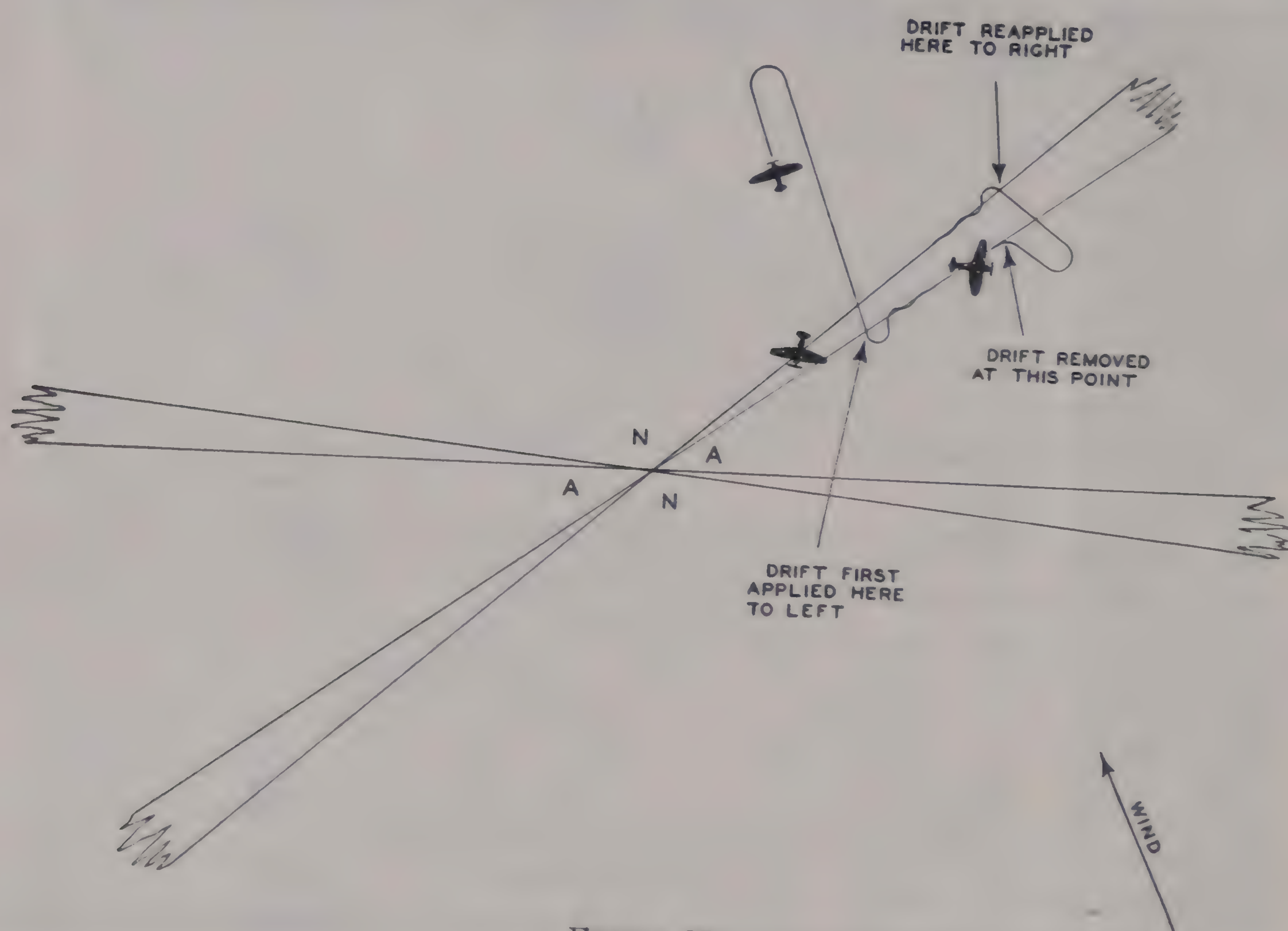


FIGURE 37.

about it until the beam is crossed. At the instant the student starts his left turn after intersecting and crossing the beam, the recorder gears should be rotated one electrical notch down wind. Since in the example being used the wind is coming from the right hand side of the beam the gears will be turned left. Thus, the heading of the trainer will be 30° to the right (into the wind) from the track drawn by the inking wheel. The track is, therefore, drifting 30° to the left, and the student must correct that amount to the right. (But don't tell him; let him find it out for himself.)

e. When the student does a procedure turn to get headed back toward the station, with drift applied, *the drift must be removed from one side and applied to the other side.* This should be done as fol-

lows (see fig. 36): When the student starts his 45° turn to the right for his procedure turn the drift should be removed. Double check the heading of the recorder against the trainer heading shown on the compass tags to be sure the gears were rotated correctly and that the drift was actually removed and not doubled by turning the gears in the wrong direction. No drift should be reapplied until the student has completed his 180° turn (plus or minus allowance for drift) and has recrossed the beam. At the instant he starts his left turn to find the beam edge again, the drift should be again applied down wind. With the student headed back along the beam the wind will be from the left (instead of from the right as before), and the recorder inking wheel must be turned to the right (fig. 36). The instructor will find that a great deal of mental alertness is required, and that he must be thoroughly awake in order to avoid forgetting to apply or remove the drift at the right time and in the correct direction. The instructor should again be warned against the inertia which will tend to have him take the easy way out by not applying drift when it should be done.

Section II

TEACHING ORIENTATION SYSTEMS

48. The 90° system.—*a.* In teaching the 90° system the recorder should be placed with the inking wheel approximately 7 or 8 minutes from the radio station. It is desirable also at the start of a problem to have the inking wheel located in the edge of the bisignal zone. With the recorder properly lined up with the trainer and located as indicated, the student should be required to do a maximum rate turn. In the meantime the trainer radio volume control and the beamshift control are set in their proper position as indicated by the position of the recorder inking wheel. After the student has made from four to eight complete turns, the radio range should be turned on. Upon hearing the radio signals the student should recover from the turn and proceed to orientate himself. Since the student is again starting a procedure which is new to him, the signals should be exaggerated

as was done in beam bracketing. As soon as the student deviates from the prescribed procedure the instructor should cut in with the microphone and straighten him out. *Do not let him wander.*

b. It is a characteristic trait in nearly all students that when they first start listening to and concentrating on radio range signals and orientation procedure they forget to keep a close watch on their instruments. The result is that students who have been doing excellent basic instrument flying previously will become erratic and careless about airspeed and altitude. The instructor, therefore, must be particularly alert during the early stages of radio orientation to prevent the student from falling into bad habits which he may afterward never be able to lose.

c. It is usually not desirable to work more than two orientation problems on the same chart. More than this number of problems on one sheet will track up the beams and make the chart difficult to follow. Before each successive problem is given to the student the instructor should check his previous charts. If one problem results in a 180° turn after identifying the leg, the next problem should be so set up that it will result in a 270° turn. If one student has to do several 90° method problems before mastering the system, care should be taken not to alternate the setting up of the problem in such a way that the student is able to anticipate or guess his position.

d. The 90° system should not, of course, be taught or demonstrated on other than a practically square station. Upon the completion of each problem the chart should be marked with the student's name, the date, and the instructor's name, and then filed for future reference.

49. True fade-out system.—In teaching the true fade-out system of orientation a scissor station pattern should be selected. The recorder should then be placed in one or the other of the large open sectors. It is desirable about two-thirds of the time to select the position for the inking wheel so that after the student has intersected the beam and bracketed it he will be going away from the station. This will give him further practice in checking the fade and also in maneuvering on the beam. Particular care must be taken by the instructor to insure that the student is not identifying the beam by the compass heading. It is not sufficient to ask the student how he identified the beam; rather, a condition should be created in which identification of the beam by compass heading alone will result in a wrong identification. (See par. 47.) If sufficient drift is applied on a scissor station such as, for example, Buffalo, N. Y., a condition can be set up whereby the student can be flying out one beam away from the station with almost the exact in-bound heading of the other beam.

If under these conditions he identifies the wrong beam it is prima facie evidence that he is using the compass instead of the fade. In placing the recorder for true fade-out problems, it should be placed far enough from the center of the sector so that the student will encounter a beam far enough from the station to have plenty of room to bracket it down. Throughout this system or in any other system involving the student's checking a fade, it is essential that the volume control be handled smoothly and with extreme care in order to give the student the right kind of information.

50. Parallel and parallel-perpendicular systems.—In teaching these systems, a scissor station should be selected as was done with the true fade-out. The recorder, however, in this case should be placed in one of the narrow quadrants (bearing in mind that neither of these systems can be depended on in an open quadrant). If a doubtful student should insist that the parallel system will work in an open sector, the instructor should at the start of the problem place the inking wheel of the recorder well out in one of the open sectors and apply drift away from the station. Under this condition ample proof can be shown of what happens to the parallel system. To demonstrate that the parallel-perpendicular system will not work in a wide open sector, the recorder should be placed far enough to one side of the sector so that the perpendicular heading will encounter the wrong beam.

51. Fade-out 90° system.—This system may be taught on any station pattern but should never be attempted in a wide-open sector. If it becomes necessary to demonstrate that it will not work in a wide-open sector, place the recorder in such an open sector with a strong drift away from the station. That part of the sector should be selected which will permit the recorder to intersect that beam which is on the pilot's left as he approaches the station. Under these conditions the plane will be drifted back across the beam, and the pilot will receive misinformation to the effect that he is on the other beam.

52. Lost on beam system.—*a.* The recorder should be placed at a point well out on the selected beam and the beam should be about half again as wide as is ordinarily used. Leave the recorder turned off until after the student has done his full rate turn and has recovered from it and has started a turn toward the proper heading.

b. The problem can be done several times in a half-hour lesson, and the recorder should be set on a different beam for each attempt. The position relative to the center of the beam should also be varied so that in one case the student will get squared away on his new heading

before reaching the beam edge, and in another case he will still be turning toward this heading when he runs out of the beam.

c. In teaching and practicing this system, excessive time should not be wasted following the edge of the beam after it has been identified, since the purpose of the procedure is simply to identify the beam. When this has been accomplished the problem is over and a new one should be started without waste of time.

53. Close-in procedure.—In practicing this method the recorder should be placed within about 1 minute of the station, the switch left off, and the student instructed to do the full rate turn. When he hears the radio range come on, he should stop the turn and then immediately start a standard rate turn to the out-bound heading of the beam which passes over the field. As soon as he has proven the fade and turned around and crossed back over the station the problem is completed. At least two, usually three, of these procedures can be done in a 30-minute session.

54. Instrument landings.—*a.* Instrument landing training should be conducted in accordance with the principles laid down in Air Corps Technical Order 05-1-5. This training should be given only to pilots who have qualified in the instrument flying test prescribed by Air Corps Circular 50-1. In this section the words "student" and "instructor" designate, respectively, any persons who take and who immediately supervise the course.

b. The following test is to be given: Three consecutive instrument landings of an airplane, while under the hood or otherwise suitably enclosed, will be made. These landings must be completed to the end of the roll of the airplane and will start at any altitude desired, but at the time the airplane is to be not less than 10 miles from the field where landing is to be made. Any assistance given by the safety pilot, from the time the hood is closed to the end of the roll after landing, will be considered as invalidating that particular flight.

c. Instrument landings are accomplished by executing with a high degree of precision certain maneuvers which are accurately combined in a standardized pattern regulated by the pilot's observation of radio signals. As seen in plain view, the pattern is fixed relative to terrain by two key points on the ground, each of which has a radio transmitter (compass locator) and a marker beacon projector. The outer key point must be reached at a certain altitude measured by the pilot's altimeter. After reaching the outer key point, the airplane is held steadily in a precisely standardized maneuver (power glide) which will result in automatic landing on contact with the airdrome, and which should cause the inner point to be automatically reached at

a certain lower altitude. Failure to reach the inner key point at the prescribed altitude is a signal to the pilot to compensate for some previous error by use of the throttle or to go around again.

d. The instrument-landing course is divided into subcourses in the manner indicated below:

(1) Study of Air Corps Technical Order 05-1-5 and these instructions. Good general knowledge; detailed familiarity with training routine and maneuvers.

(2) Practice of maneuvers in airplane—high accuracy in each.

(3) Practice of routine in ground trainer, time required about 2½ hours; ability to make simulated landings so as to touch the ground within about 500 feet of the prescribed point; good control of altitude.

(4) In the ground trainer, the automatic recorder is used to show a record of each simulated circuit.

(5) On command from the instructor, student opens throttle, holds gyro on zero, and causes instruments to hold maximum climb by use of controls. The airplane takes itself off.

(6) At a suitable altitude the student changes instruments to fast climb.

(7) Student initiates offset turn while still climbing, but goes to medium cruising when 800 feet altitude is reached. When the offset turn brings up the 90° mark on the gyro, the radio compass volume is increased to show about one-half scale deflection.

(8) The turn is stopped so as to center the radio compass, and the pilot flies to the inner station at (or above) 1,000 feet altitude, reducing radio volume as desired.

(9) On getting marker beacon flash from inner station, student rapidly—

(*a*) Tunes to outer station and raises volume.

(*b*) Centers compass.

(*c*) Resets gyro to 180° but flies by radio compass.

(10) On getting outer station flash, being still about 1,000 feet altitude, check heading for 180° on gyro; student executes offset turn, controlling compass volume so as not to permit excessive deflection or annoying sound. As 270° comes up on the gyro, student turns up volume. Compass is centered and held centered. Altitude is slowly lost to 800 feet.

(11) Somewhere before reaching outer station again, the airplane is put in slow cruising.

(12) At outer station flash, the following things are done as nearly simultaneously as possible:

(*a*) Tune inner station, raise volume.

(*b*) Center compass, reset gyro if necessary.

(*c*) Put airplane in power glide.

(13) Maintain power glide and follow compass. Arrive over inner station at 200 to 220 feet altitude.

(14) Swing to zero on gyro; concentrate on gyro and artificial horizon. Reduce radio volume. Discontinue use of radio compass at this point.

(15) At contact, close throttle and concentrate on gyro or raise hood.

(16) When the routine is given in the ground trainer, an assistant reads and signals altitude every 100 feet from the start of the power glide to zero altitude. The instructor marks these altitudes on the chart at the proper places. The last mark (zero) represents the place of simulated landing in relation to the outline of the airdrome printd on the chart.

(17) The following explanation will indicate points to be concentrated on in practicing and executing the power glide:

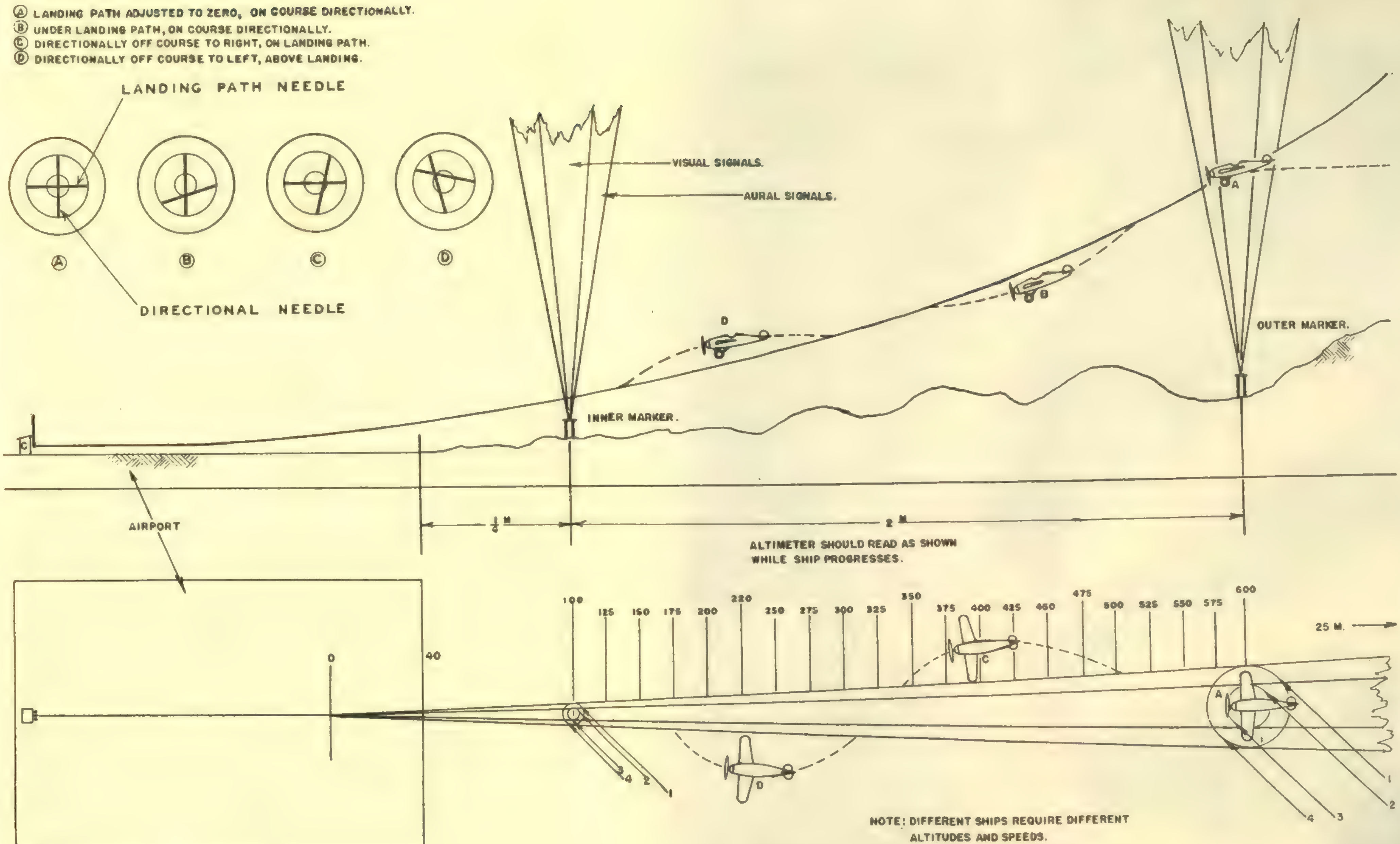
(*a*) Control of artificial horizon gives greatest difficulty. This is because an almost invisible change in the pitch indication corresponds to a considerably raising or lowering of the ship's nose.

(*b*) Control of the radio compass is next most difficult; slow up the movement of the center mark as it approaches the pointer.

55. Instrument landing system (using the cross pointer indicator).—This system incorporates the use of directional and glide path indicators. The instructor watches the progress of the recorder and the altimeter and transmits suitable signals by means of the radio controls.

a. Marker beacons.—There are two marker beacons employed, the inner marker and the outer marker. These beacons are located in line with the runway to be used. The directional beam sent from the station at the end of the runway passes directly over these two beacons. The inner beacon is located approximately 1/4 mile from the end of the field, and the outer beacon is located 2 miles from the inner beacon. These distances may be varied upon installation to suit the particular requirements of the ship being used and also to suit the terrain.

b. Landing procedure.—(1) The student tunes in the directional signal when he gets to the field. The instructor provides this signal by switching on the flight path indicator switch which is located in the small control box alongside the radio in the desk. From the time the directional beam is picked up until the outer marker beacon is passed over, the only signal the student receives is the



Ⓐ LANDING PATH ADJUSTED TO ZERO, ON COURSE DIRECTIONALLY.
Ⓑ UNDER LANDING PATH, ON COURSE DIRECTIONALLY.
Ⓒ DIRECTIONALLY OFF COURSE TO RIGHT, ON LANDING PATH.
Ⓓ DIRECTIONALLY OFF COURSE TO LEFT, ABOVE LANDING.
LANDING PATH NEEDLE
Ⓐ
Ⓑ
Ⓒ
Ⓓ
DIRECTIONAL NEEDLE
VISUAL SIGNALS.
AURAL SIGNALS.
OUTER MARKER.
INNER MARKER.
AIRPORT
ALTIMETER SHOULD READ AS SHOWN
WHILE SHIP PROGRESSES.
100
125
150
175
200
220
250
275
300
325
350
375
400
425
460
475
500
525
550
575
600
25 M.
0
40
NOTE: DIFFERENT SHIPS REQUIRE DIFFERENT
ALTITUDES AND SPEEDS.

FIGURE 38.

directional signal which is given by the instructor by means of the E and T beam shift control. When the beam shift control is on center or zero the indicator in the cockpit will be at zero. Off-course is shown in a similar manner. When more sensitivity is wanted, the instructor can regulate the course indicator deflection control to give the needle of the directional indicator more "kick." The direction of "kick" is governed by the way the instructor has the beam shift off center.

(2) The student starts to receive the outer marker beacon signals at point 1. The instructor gives him the aural signal by switching the pointer of the beacon selector to outer and gradually increasing the volume. As the instructor continues to increase the aural volume, the volume control closes the circuit to the visual marker at point 2. When the student receives the visual signal, he immediately sets his landing path needle to zero by means of the volume control in the cockpit, at the same time starting his descent. As can be seen from figure 38, the student should be at certain definite altitudes as he progresses along his course toward the landing field, following the directional beam. The instructor notes the altitude on the desk altimeter as the flight log progresses, and if the altitude is too low he moves the glide path indicator control so that the needle will be below zero. This indicates to the student that he is below the beam, and vice versa if above. The control for the glide path indicator is on the small control box above the flight path switch.

(3) As the inner marker beacon is approached and passed over, the proper signals are given after switching the beacon selector to inner. The signals are given by the instructor in the same manner as the signals for the outer beacon were given at point 2.

(4) As the student gets out of range of the marker beacon (range is marked on the map, fig. 38), the instructor starts to turn back the volume control to the beacons, automatically shutting off the visual signals as he passes point 3. The aural signals should be made to diminish gradually until at point 4 these are gone also. After that, the marker beacon selector switch can be switched to "off."

(5) During this time the instructor should be constantly on the alert, watching the progress of the recorder and the altitude flown, and giving the proper indications to the student. When the altimeter reads zero the student should raise the hood or otherwise signal, and if the recorder is at the proper point on the runway the landing is a success.

Chapter 4

RADIO AIDS TO NAVIGATION

Section I

RADIO COMPASS

56. General.—*a*. There are occasional situations when radio range orientation is inadequate due to excessive false fades, swinging beams, etc. There are also many occasions, especially in military flying, when radio beams are not available, such as over-water flights and cross-country flights which do not coincide with civil airways.

b. The radio compass or direction finder in such cases provides another means of obtaining a "fix" or position and also a means of "homing" directly to a given station.

(1) There is some confusion regarding the difference between a radio compass and a direction finder. For the purpose of this manual, radio compass will be used to indicate all types of radio direction finders.

(2) All radio compasses utilize as a fundamental principle the fact that certain types of antennas are highly directional, and when the source of energy (radio transmitting station) bears certain angular relations to the plane of the antenna, the ratio of response (volume) of the received energy will be evident to the observer through suitable indicating instruments. Different designs of radio compasses indicate

this maximum or minimum by various methods, i. e., left-right indicator, neon light, "null" in earphones, minimum or maximum indications on a suitable meter, etc. These include the more commonly used left-right radio compass, homing devices, aural-null direction finders, etc. The antennas usually take the form of a loop which has maximum response when the plane of the loop is in line with the radio transmitting station (fig. 39A) and minimum response when the axis of the loop is in line with station (fig. 39B).

(3) There are two types of radio compasses; those with a loop fixed to the airplane, and those with a rotatable loop which can be rotated and controlled from the cockpit. There are also two types of indications; visual, by means of a left-right indicator, and the aural-null method in which the minimum signal is used as the reference.

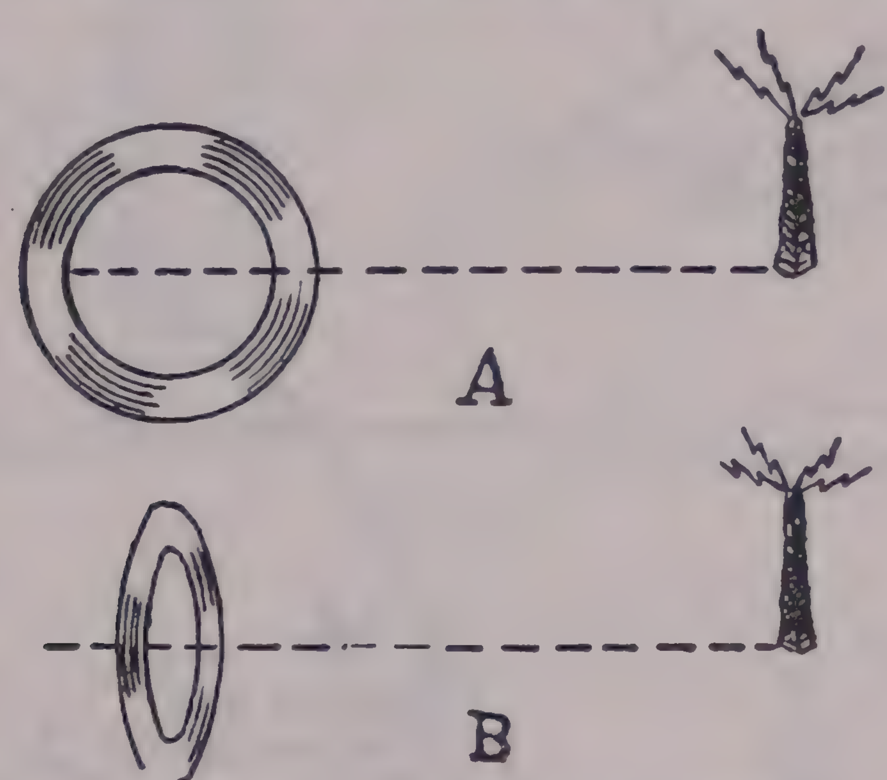


FIGURE 39.—Obtaining bearings.

57. Fixed loop radio compass.—*a.* After tuning in the desired station it is necessary to determine whether the station is in front or behind. With the visual indicator this is relatively simple. The needle may be centered with the station either in front or behind it, but if the station is behind the indications of the needle will be reversed.

b. The indicating needle points toward the station, i. e., if the needle is to the right, a right-hand turn is required to center it. To avoid loss of time when the station is first tuned in, the pilot should start a standard rate turn to the right and continue the turn until the needle comes from right to center. Homing with this device is then only a matter of keeping the radio compass needle centered. If there is a cross wind the track to the station will not, however, be in a straight line.

58. Fixed loop using aural null.—Using this method the radio station is tuned in and a standard rate turn is started and continued

until a minimum signal strength is received. The volume control should be adjusted to give as narrow as possible a null. The station may then be either in front or behind. There are two methods of solving this ambiguity. If another station is available and can be tuned in, a line of position may be obtained from both stations and the resulting fix will determine the direction to the station. (This is called "triangulation" and will be taken up in detail later.) The other method is as follows: Note the bearing of the null, then turn 90° to the left and fly this heading for several minutes. Then turn to the right until the null is again found. If the bearing of the null is now less, the station is behind; if the bearing is greater, the station is in front. (See fig. 40.)

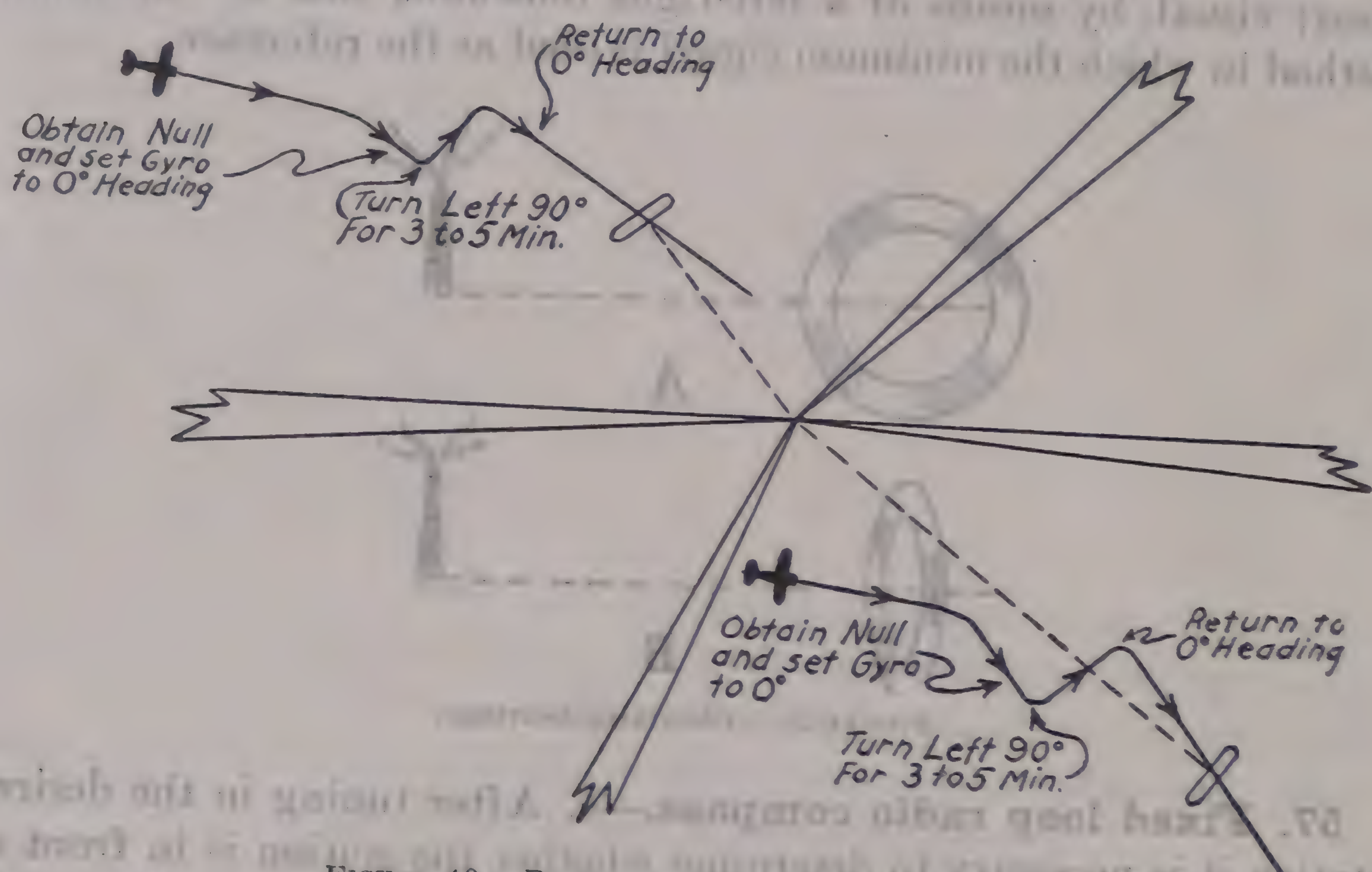


FIGURE 40.—Bearing using aural-null method.

59. Obtaining bearings.—*a.* In order to obtain bearings with these radio compasses it is necessary to use the maximum or minimum response indication as a reference to determine when the azimuth needle is in a correct position to be read. In practice this is accomplished by remote rotation of the loop until the indicating instrument shows the desired indication, and then observing the bearing as shown by a needle which is mechanically linked with the loop antenna and rotates across the face of an azimuth scale.

b. The angular bearing thus indicated is that of the radio station relative to the nose of the aircraft, and is equivalent to the bearings obtained by the navigator of a ship at sea using a pelorus and sighting on an object (such as a lighthouse) on shore (fig. 41). The bearings taken by the radio compass are in fact an extension of the visual

method utilizing radio waves, of course, instead of light waves as a medium for transmission.

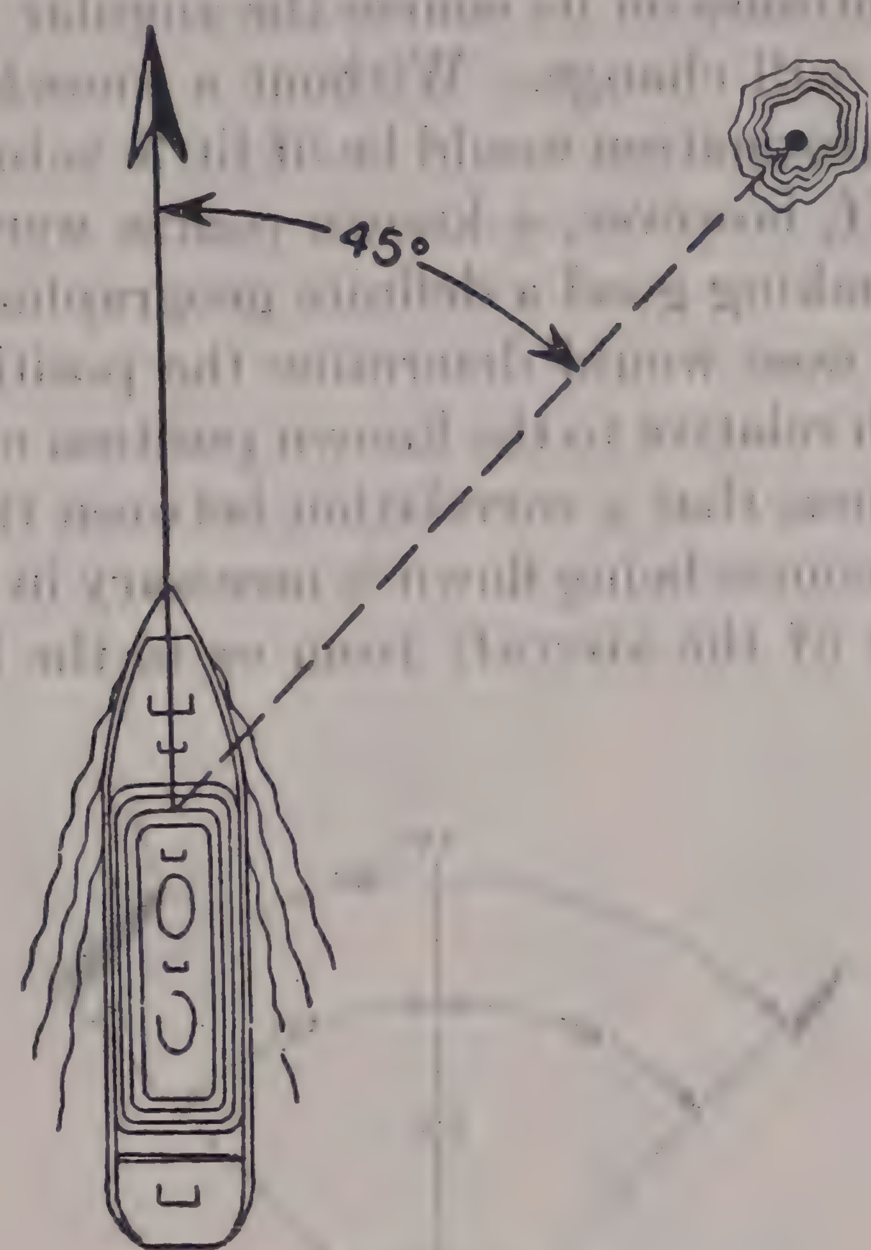


FIGURE 41.

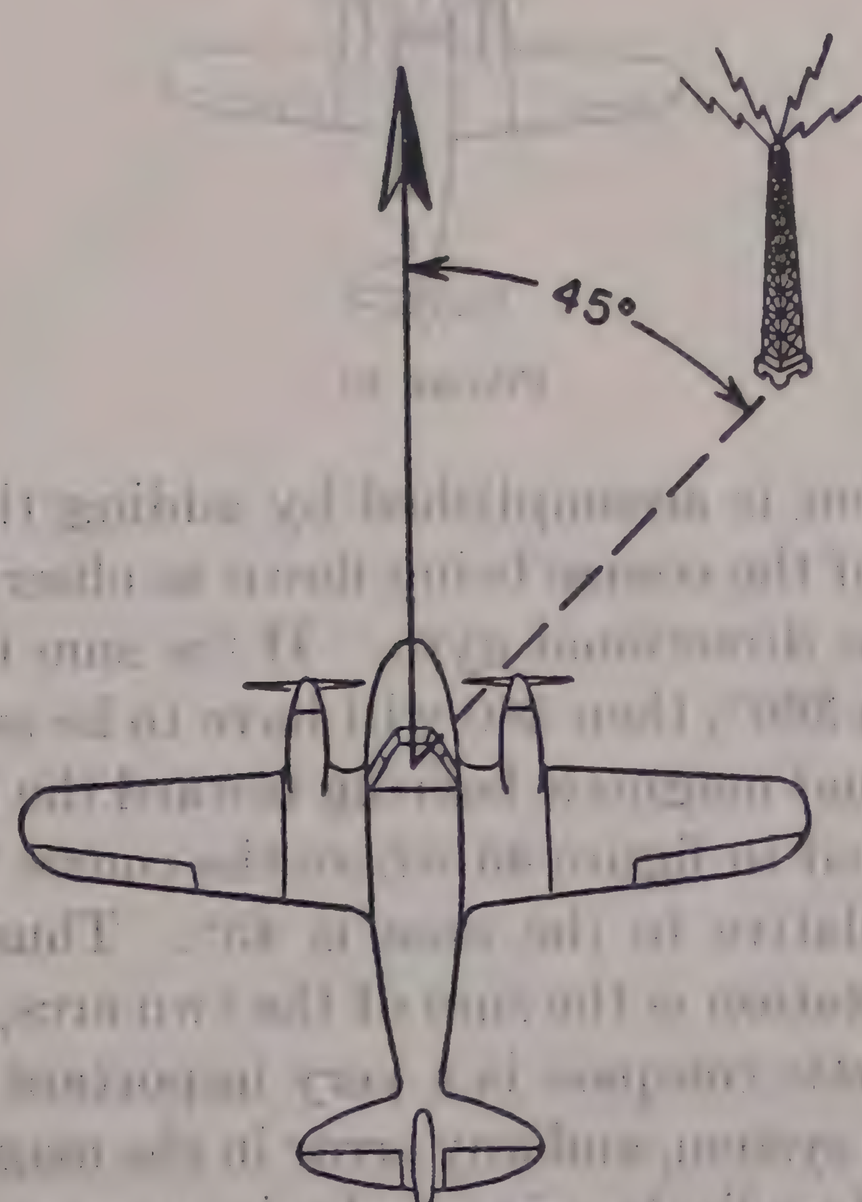


FIGURE 42.

c. By reference to figure 42 it will be seen that the bearing of 45° obtained by the radio compass is only relative to the nose of the airplane. If the ship in figure 41 or the airplane in figure 42 changes its

course by as much as 1°, the angular bearing relative to the nose (or bow) will change in exact proportion. It will also be seen that as the ship or aircraft continues on its course the angular bearing relative to the nose (or bow) will change. Without a knowledge of the course being flown, this information would be of little value in determining a line of bearing. If, however, a known course were being flown and the aircraft were making good a definite geographical track, the bearing relative to the nose would determine the position of the aircraft along its flight path relative to the known position of the radio station. It is therefore obvious that a correlation between the bearing relative to the nose and the course being flown is necessary in order to determine the line of bearing of the aircraft from or to the known position of the radio station.

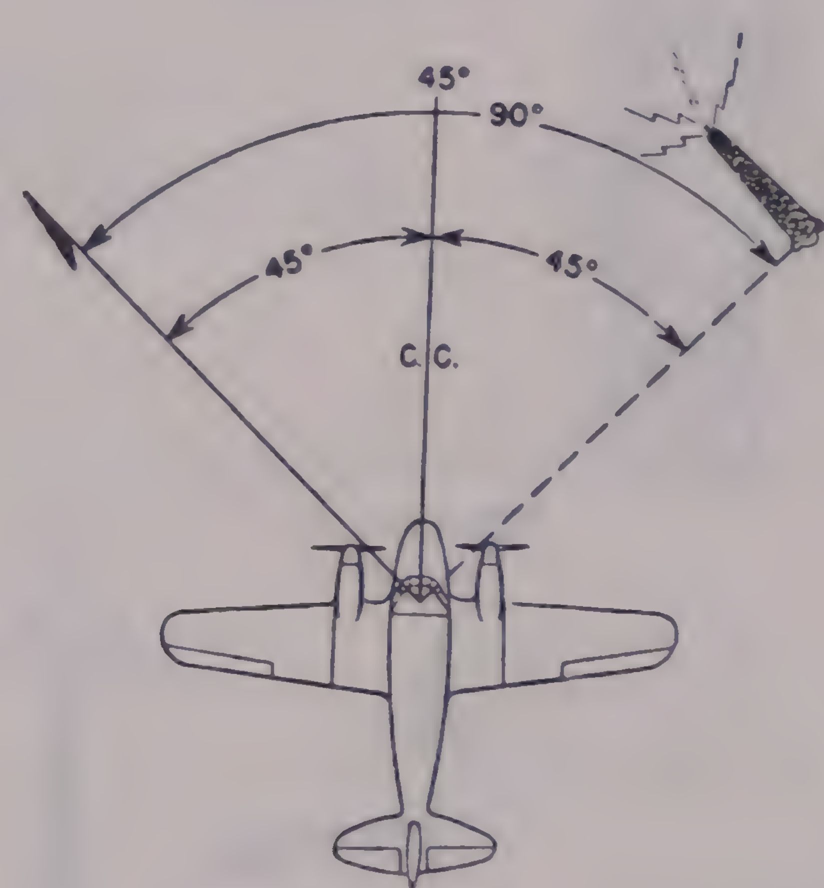


FIGURE 43.

d. This correlation is accomplished by adding the bearing relative to the nose to that of the course being flown as observed from the magnetic compass or the directional gyro. If the sum total of these bearings is greater than 360°, then 360 will have to be subtracted from the total to find the actual magnetic bearing toward the radio station. An example is illustrated in figure 43 where the course being flown is 45° and the bearing relative to the nose is 45°. Thus the true bearing (magnetic) of the station is the sum of the two arcs, or 90°. It will be seen that the magnetic compass is a very important part of any radio compass navigation system, and any error in the magnetic compass will cause the computed radio bearing to be in error proportional to the error of the magnetic compass.

e. Figure 44 shows an airplane flying a course of 240°, and a bearing is taken which shows the radio station to be 250° (using an azimuth indicator as shown in figure 45) relative to the nose of the airplane. By

adding the radio compass bearing to the magnetic course, a figure of 490° is obtained. Obviously this is greater than 360° and therefore 360 must be subtracted from this figure, which shows the magnetic course toward the radio station to be 130°.

f. A variation of this method must be exercised when the radio compass azimuth scale is split as shown in figure 46. In this case the

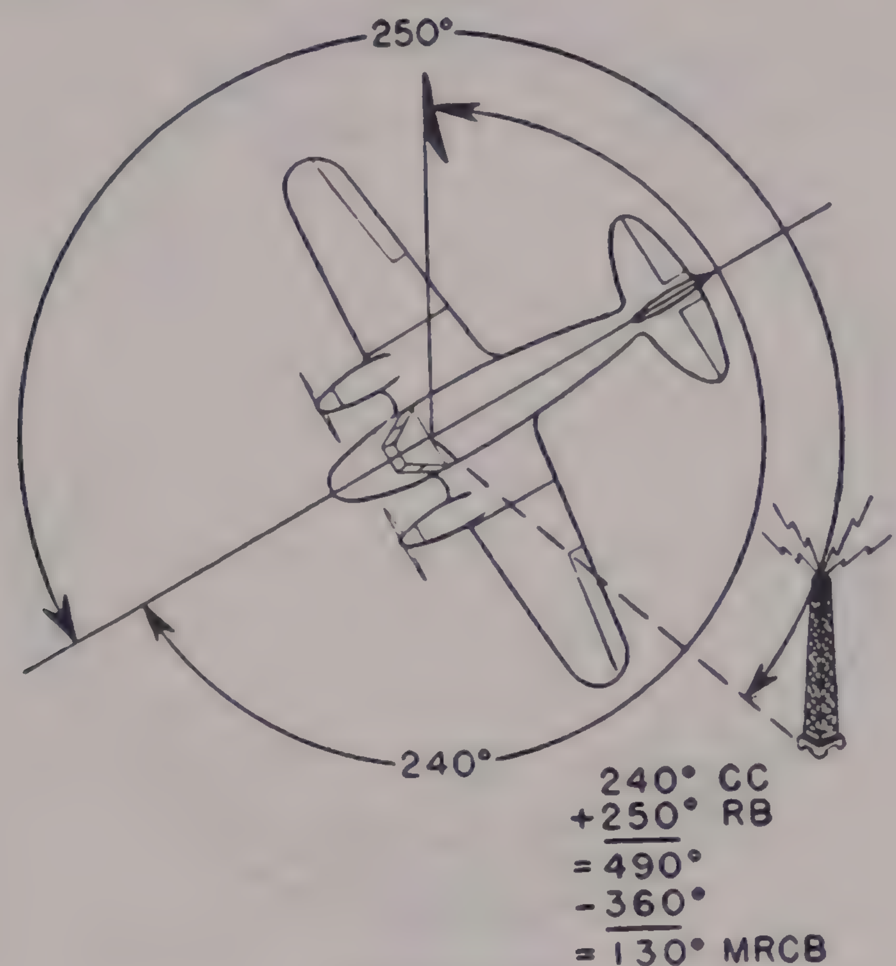


FIGURE 44.

FIGURE 45.

bearings indicated are also relative to the nose of the plane but are designated as port or starboard bearings. Starboard bearings (as indicated on the azimuth scale) are additive and port bearings are subtractive from the magnetic course. In any case where the sum total of the radio compass bearing and magnetic course is greater than 360°, the figure 360 should be substracted from the sum total to obtain the computed magnetic bearing of the station from the airplane.

60. Establishment of fixes.—Thus far we have been concerned with the establishment of lines of bearings only. If while maintaining position on a radio beam a line of bearing is established, the resultant of the two lines (radio compass computed bearing toward the station and radio range course) extended to a point of intersection will establish a position of "fix." A fix may be obtained by developing

FIGURE 46.

FIGURE 47.

two lines of bearings from two stations separated geographically sufficient to produce a differential in bearing greater than 30°. A line of bearing from a third station will materially aid in determining the accuracy of the fix computed from two stations (fig. 49).

61. Magnetic variation.—Thus far no allowance has been made for the factor of magnetic variations as published on all aeronautical charts. Inasmuch as any error of the magnetic compass will cause

an error of equal magnitude in the computed radio compass bearing, it is obvious that variation affecting the magnetic compass must be taken into consideration in computing radio compass bearings. The factor of variation may cause errors of as much as 25°, depending on the particular section of the country over which the airplane may be flying. Variation should be added or subtracted, as the case may

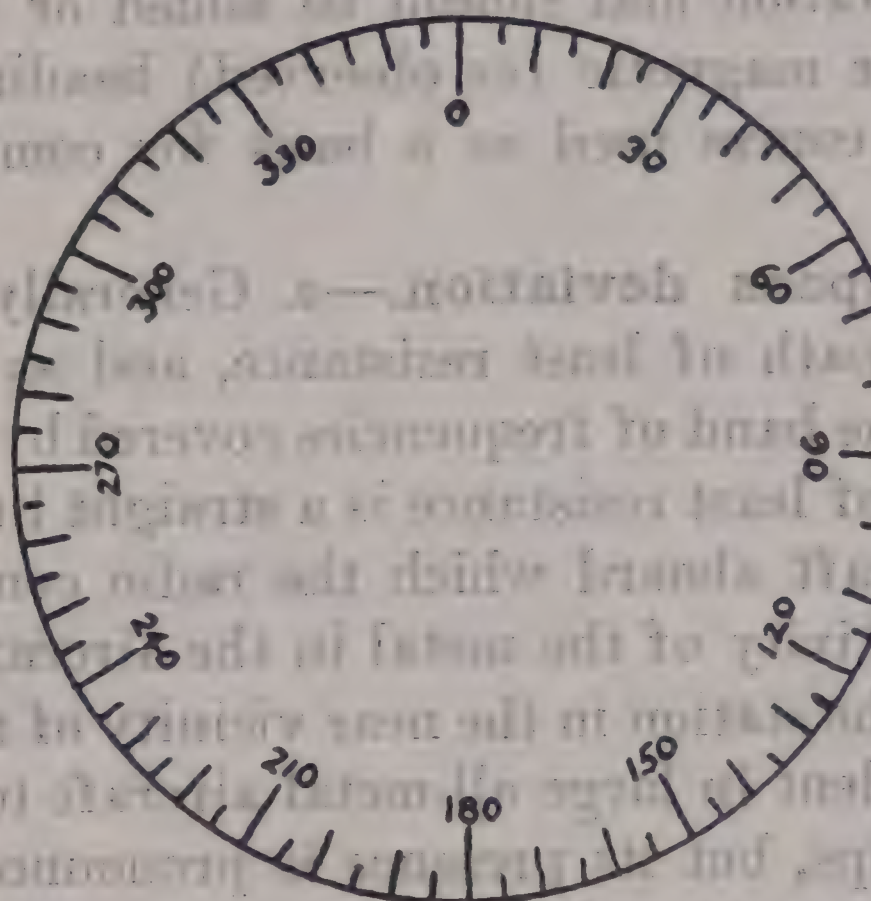


FIGURE 48.

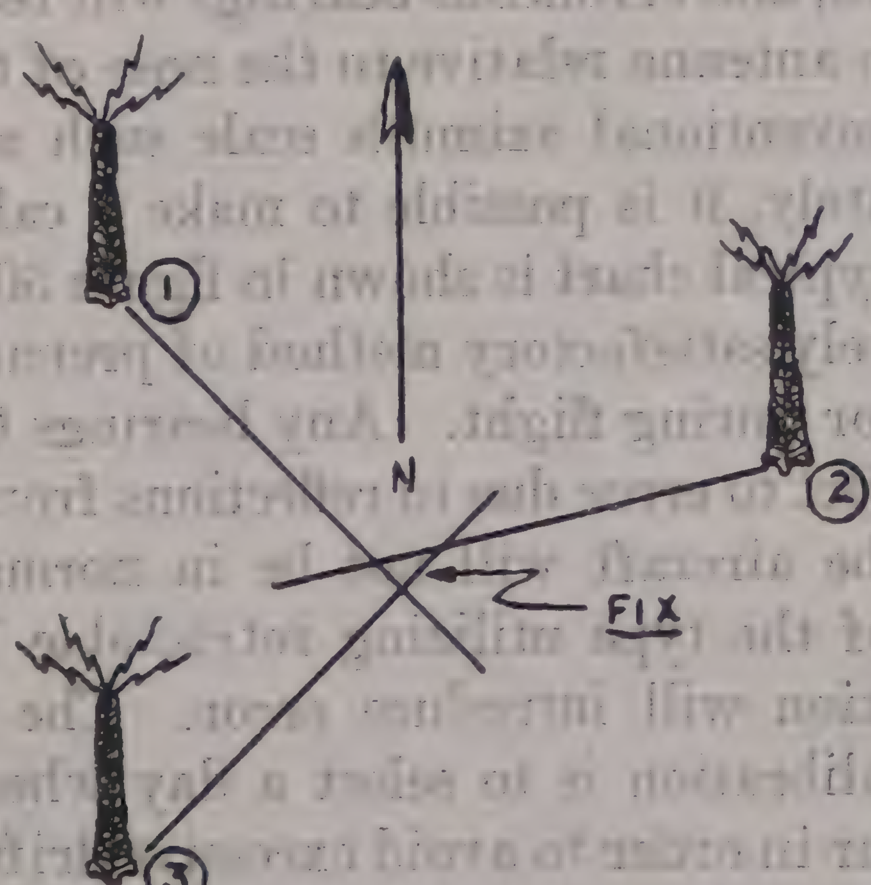


FIGURE 49.

be, based on the advertised variations existing at the approximate location of the airplane rather than at the radio station. In general it is permissible to disregard the difference of variation existing between the aircraft's location and the radio station when the distance involved is not greater than 100 miles. However, this factor should be reckoned with, if bearings are taken over long distances, particularly in the extreme northeast and northwest sections of the United States where the lines of equal variation are close together.

62. Magnetic compass deviation.—Magnetic compasses aboard aircraft are usually compensated only at the northeast, south, and west points. The error existing at other points of the compass is usually determined and shown on a correction card attached to or near the compass. This error may be as great as 5° or 6°. For greatest accuracy in computing radio compass bearings this error must be taken into consideration and should be added or subtracted, as the case may be, to the magnetic (as observed) heading of the aircraft and the corrected course used as a basis for computation of radio compass bearings.

63. Radio compass deviation.—*a.* Generally speaking, radio waves follow the path of least resistance, and as a rule it may be assumed that for the band of frequencies covered by the average radio compass this path of least resistance is a straight line from the transmitter to the aircraft aboard which the radio compass is installed. The higher conductivity of the metal in the aircraft tends to distort the wave front of the station in the near vicinity of the aircraft. This phenomenon is evident in large all-metal aircraft to a greater degree than in smaller ships, but its presence is pronounced in all types of aircraft. The loop antenna of the radio compass is therefore subjected to this distorted field, and erroneous bearings will result if the physical rotation of the loop antenna relative to the nose of the aircraft is read directly from a conventional azimuth scale such as shown in figure 45 or 46. Fortunately, it is possible to make a calibration chart for such errors, and a typical chart is shown in figure 50.

b. The only entirely satisfactory method of preparing such charts is to ascertain the error during flight. Any bearings taken while on the ground may be subject to error due to reflections from buildings, power lines, etc. Also, the aircraft will not be in normal flying position, especially if it is of the type utilizing retractable landing gear, and the tail-down position will introduce error. The most satisfactory method of flight calibration is to select a day when the wind is less than 8 miles per hour in order to avoid excessive drift angles. A highway which is in direct line with a radio range or broadcast station should be selected and used as a reference point. The position of the highway being used during these calibration flights should be not less than 15 or more than 50 miles from the radio station (fig. 51).

c. The method of calibration is substantially as follows: With a plain paper disk pasted over the azimuth scale usually furnished with the equipment, the ship is flown exactly down the highway at an altitude low enough to overcome parallax effect. The loop is then rotated to obtain the desired response on the indicating instru-

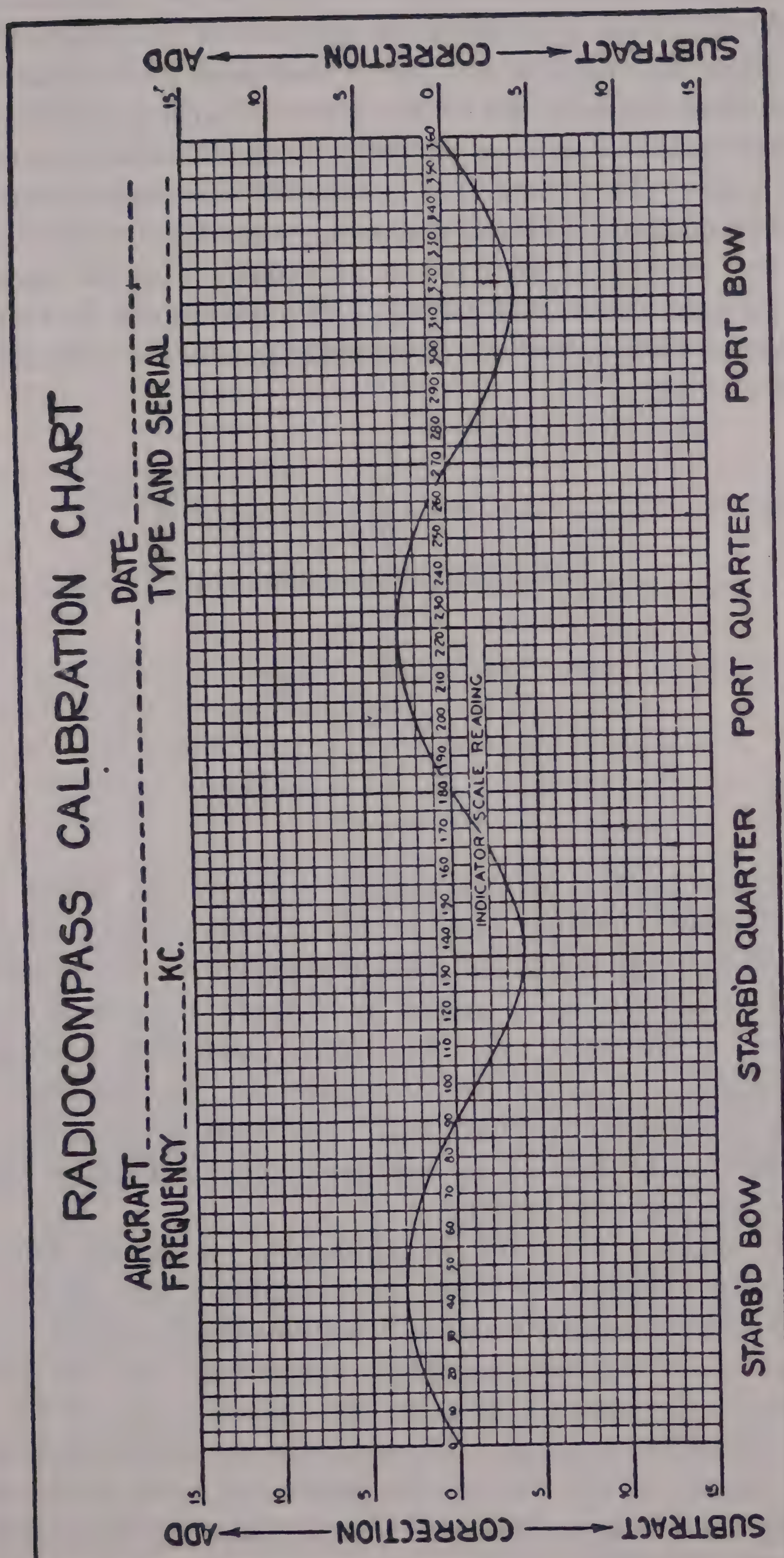

RADIOCOMPASS CALIBRATION CHART
AIRCRAFT
DATE
FREQUENCY
KC.
TYPE AND SERIAL
ADD ← CORRECTION → SUBTRACT
15 10 5 0 5 10 15
INDICATOR SCALE READING
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280 290 300 310 320 330 340 350 360
STARB'D BOW
STARB'D QUARTER
PORT QUARTER
PORT BOW

FIGURE 50.

ment (needle centered or null in earphones), and the position of the needle on the azimuth scale is then marked on the blank paper disk. At this time the directional gyro is set exactly to 0°. A turn is then made and the plane is flown back across this road at a predetermined point at an angle of 15° port or starboard, and the position of the azimuth indicator is ascertained and marked to correspond to the 15° angle. This maneuver is repeated for each of the 15° points around the compass. Greater accuracy may be obtained by changing course 10° instead of 15°, but it is usually easy to interpolate the results between the known points. The results can be transferred to a permanent disk to replace the evenly graduated azimuth indicator (figs. 47 and 48).

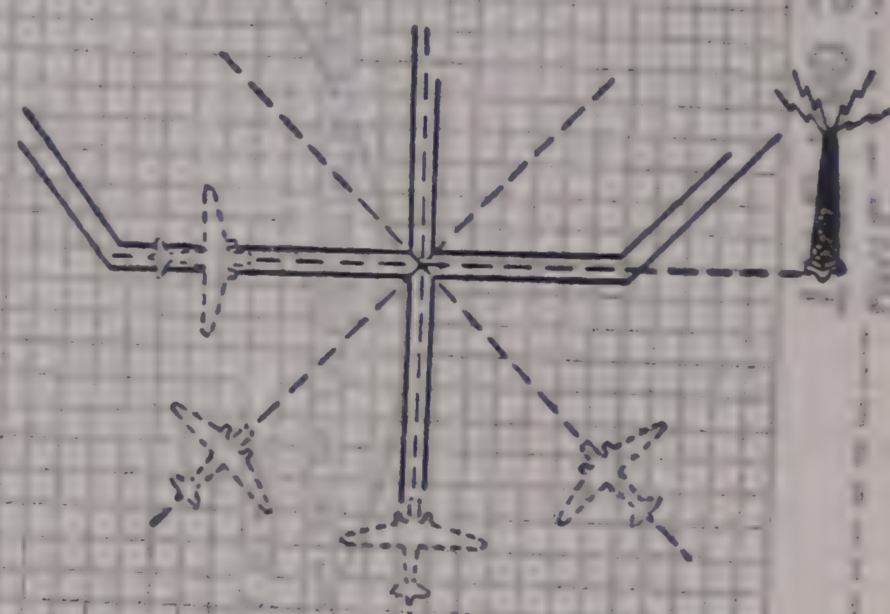


FIGURE 51.

d. Another method of calibration is to fly the course exactly as described above, making note of the difference between the evenly graduated azimuth scale and that registered by the azimuth needle. This difference will be expressed as so many degrees to be added or subtracted as the case may be. From these data a chart may be drawn similar to that shown in figure 50. In this case it will be necessary to refer to the chart with each bearing and make the necessary correction by adding or subtracting the difference between the indicated and the true bearing.

e. Still another variation in automatic correcting for error due to distortion of the wave front is to employ a cam device as a part of the azimuth indicator which will automatically retard or accelerate the speed of the azimuth needle to compensate for the error. This cam is cut on the basis of the error determined in any of the approved methods of calibration and will permit the use of an evenly graduated azimuth scale. With the evenly graduated scale it is possible to rotate this scale independently of the movement of the azimuth needle.

This will permit the scale to be set to a lubber line representing the nose of the airplane. With the scale thus rotated to the course being flown, true magnetic bearings will be indicated without the necessity of computation. A simplification (from a navigation viewpoint) of this device would be to use a compass "repeater" to maintain the radio compass azimuth scale in synchronization with the plane's magnetic or directional gyro compass, which holds its position relative to magnetic north irrespective of the movement of the ship or rotation of the radio compass loop.

64. Procedure in taking bearings.—*a.* With all of the variable elements entering into the operation of radio compasses, too much emphasis cannot be placed on attention to detail. The following chronological order should be observed in taking bearings:

(1) Steady down on course.

(2) Obtain radio compass bearing, simultaneously observing course being flown.

(3) Note time bearing was taken to as close a fraction of a minute as practicable.

(4) Compute radio bearing and magnetic bearing to ascertain true magnetic bearing of the radio station.

NOTE.—No deviation should be made from the sequence given above.

b. Great attention to detail is absolutely necessary due to the many points where error may be introduced by such inattention. Parallax effect in reading of instruments may introduce errors as great as 1° to 2° if the instrument needle and scale are not directly in line with the operator's line of vision. It is very important that the gyro compass be accurately caged with the magnetic compass if the course is determined from the gyro, as any error introduced by this detail will show a proportional error in the computed radio compass bearing. Parallax effect in reading the magnetic or gyro compass should be avoided as this is another source where error may be introduced.

c. In the computation of bearings to ascertain the speed of the aircraft the element of time is very important, and too much emphasis cannot be placed upon accurately reading the clock simultaneously with the reading of the azimuth indicator and gyro or magnetic compass. (See form below.)

DIRECTION FINDING FORM

1	2	3	4	5	6	7	8	9	10	11	12	13
Station	Fre-quency	Time	Deviation +east −west	Variation +east −west	Airplane compass heading	True heading	Radio compass bearing	Radio compass correction	True radio compass heading	Bearing from air-plane to station	Bearing station to air-plane	Error

DIRECTIONS: Column 1, call letters of station; 2, frequency; 3, time bearing was taken on that station; 4, deviation of magnetic compass; 5, magnetic variation (note compass card for deviation; if steer is greater than for deviation, variation is west, if less east. Westerly deviation and variation is subtracted from the compass heading for true course while easterly is added); 6, magnetic compass heading of airplane; 7, true heading of airplane; 8, reading of azimuth on radio compass loop; 9, correction if any (east would be added, etc.); 10, true radio bearing if correction card is made for radio compass; 11, true bearing from airplane to station, which is the true course plus reading on radio loop (minus 360 if sum is greater than 360); 12, true bearing from station to airplane which is the reciprocal of 11 (if the answer in 11 is less than 180, add 180; if greater than 180, subtract 180); 13, for instructor as to error in miles.

65. Homing.—*a.* Homing is the procedure involved in flying to a radio station by the use of the direction finder without regard to position fixes obtained from other off-line stations. In homing, the plane of the loop is rotated until the indicating needle on the loop azimuth scale points to zero, and then a null is maintained in the earphones, or in the case of visual indicating radio compasses the needle is centered. As long as the proper indication is received on the indicating instrument (null in earphones or needle centered), the ship's nose will always be pointed toward or away from the station.

b. The effect of wind drift is shown graphically in figure 52, and due allowance for wind must be exercised if a definite geographical track must be maintained.

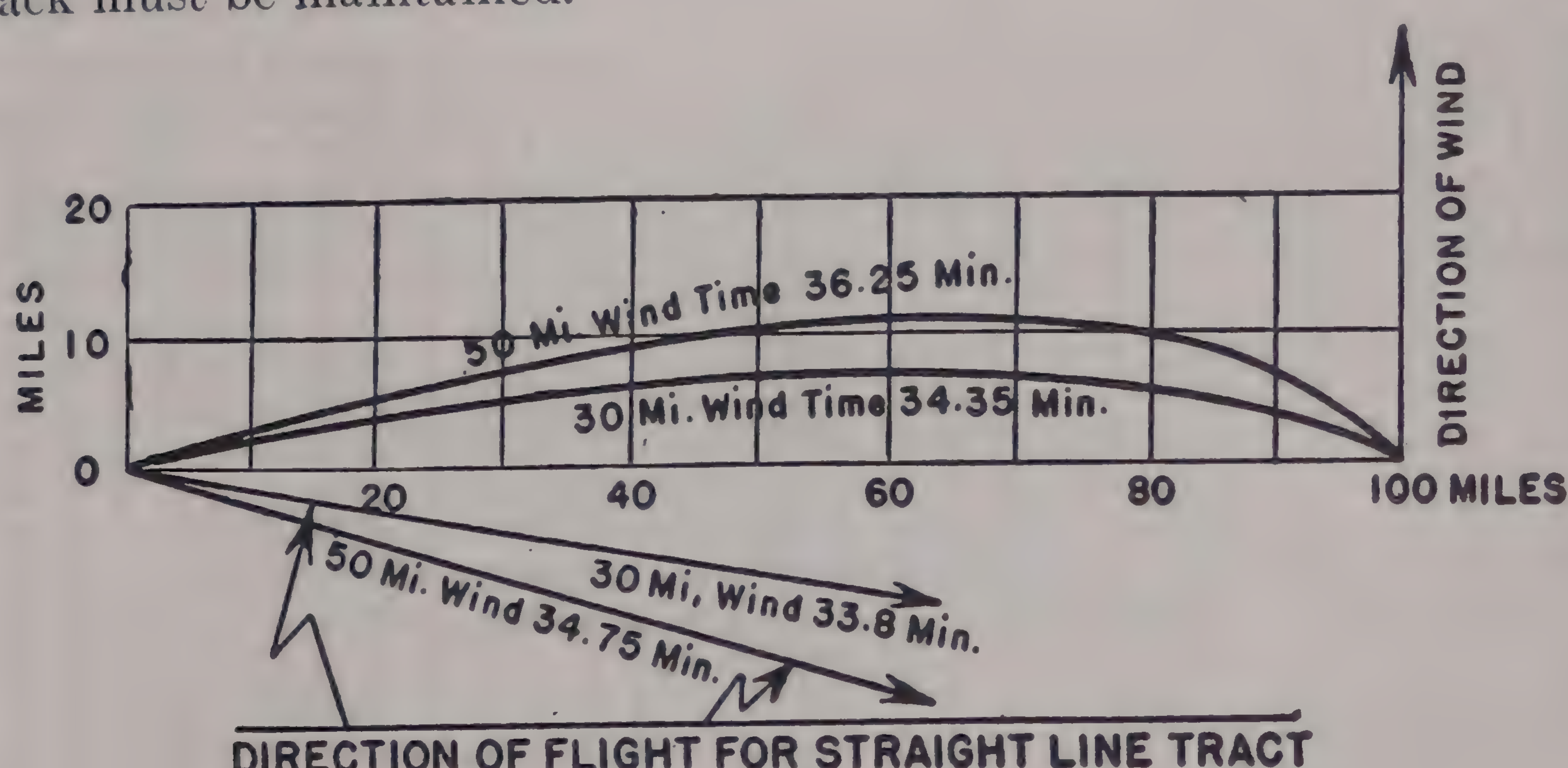


FIGURE 52.—Data for airplane of 180 miles per hour airspeed.

66. Correction of radio bearings.—Although radio bearings are considered less accurate than results possible with dead reckoning, the development of radio equipment is making radio bearings more reliable. As radio bearings approximate arcs of great circles, they must be changed to mercator bearings before being plotted on a mercator chart. This correction is not considered necessary if the distance to the station or stations is less than 100 miles. The table following may be used to correct radio bearings. Enter table with midlatitude and DLo between the D. R. position and the transmitting station and pick out the correction necessary. This correction is additive/subtractive as the aircraft is eastward/westward of the station in north latitude, and subtractive/additive as the aircraft is eastward/westward in south latitude.

Example: An aircraft (D. R. position 32° 40′ N., 121° 15′ W.) receives a bearing of 271° from Imperial Beach (NPZ, 32° 35′ N., 117° 08′ W.).

Mid-Lat., 33°; DLo, 4°; correction, plus 1.1°.
Mercator bearing, 272.1°.

CORRECTION REQUIRED TO CONVERT A RADIO GREAT CIRCLE BEARING TO MERCATORIAL BEARING

Difference of longitude of ship and radio station

	2°	4°	6°	8°	10°	12°	14°	16°	18°	20°	22°	24°	26°	28°	30°
66	0. 9	1. 8	2. 8	3. 7	4. 6	5. 5	6. 4	7. 3	8. 2	9. 1	10. 0	11. 0	11. 9	12. 8	13. 7
63	0. 9	1. 8	2. 7	3. 6	4. 5	5. 4	6. 3	7. 1	8. 0	8. 9	9. 8	10. 7	11. 6	12. 5	13. 3
60	0. 9	1. 7	2. 6	3. 5	4. 3	5. 2	6. 1	6. 9	7. 8	8. 6	9. 5	10. 4	11. 2	12. 1	12. 9
57	0. 8	1. 7	2. 5	3. 4	4. 2	5. 0	5. 9	6. 7	7. 5	8. 4	9. 2	10. 0	10. 9	11. 7	12. 5
54	0. 8	1. 6	2. 4	3. 3	4. 1	4. 9	5. 7	6. 5	7. 3	8. 1	8. 9	9. 7	10. 5	11. 3	12. 1
51	0. 8	1. 6	2. 3	3. 1	3. 9	4. 7	5. 5	6. 2	7. 0	7. 8	8. 5	9. 3	10. 1	10. 8	11. 6
48	0. 8	1. 5	2. 2	3. 0	3. 7	4. 5	5. 2	5. 9	6. 7	7. 4	8. 2	8. 9	9. 6	10. 4	11. 1
45	0. 7	1. 4	2. 1	2. 8	3. 5	4. 2	4. 9	5. 6	6. 3	7. 1	7. 8	8. 5	9. 2	9. 9	10. 6
42	0. 7	1. 4	2. 0	2. 7	3. 4	4. 0	4. 7	5. 4	6. 0	6. 7	7. 4	8. 0	8. 7	9. 4	10. 0
39	0. 6	1. 3	1. 9	2. 5	3. 2	3. 8	4. 4	5. 0	5. 7	6. 3	6. 9	7. 5	8. 1	8. 8	9. 4
36	0. 6	1. 2	1. 8	2. 4	3. 0	3. 5	4. 1	4. 7	5. 3	5. 9	6. 4	7. 0	7. 6	8. 2	8. 7
33	0. 5	1. 1	1. 6	2. 2	2. 7	3. 3	3. 8	4. 4	4. 9	5. 4	6. 0	6. 5	7. 1	7. 6	8. 1
30	0. 5	1. 0	1. 5	2. 0	2. 5	3. 0	3. 5	4. 0	4. 5	5. 0	5. 5	6. 0	6. 5	7. 0	7. 4
27	0. 5	0. 9	1. 4	1. 8	2. 3	2. 7	3. 2	3. 6	4. 1	4. 5	5. 0	5. 4	5. 9	6. 3	6. 8
24	0. 4	0. 8	1. 2	1. 6	2. 1	2. 4	2. 9	3. 3	3. 6	4. 0	4. 4	4. 8	5. 2	5. 6	6. 0
21	0. 3	0. 7	1. 1	1. 4	1. 8	2. 2	2. 5	2. 9	3. 2	3. 6	3. 9	4. 3	4. 6	5. 0	5. 3
18	0. 3	0. 6	0. 9	1. 2	1. 6	1. 9	2. 2	2. 5	2. 8	3. 1	3. 4	3. 7	4. 0	4. 3	4. 6
15	0. 3	0. 5	0. 8	1. 0	1. 3	1. 6	1. 8	2. 1	2. 3	2. 6	2. 8	3. 1	3. 3	3. 6	3. 8
12	0. 2	0. 4	0. 6	0. 8	1. 0	1. 3	1. 5	1. 7	1. 9	2. 1	2. 3	2. 5	2. 7	2. 9	3. 1
9	0. 2	0. 3	0. 5	0. 6	0. 8	1. 0	1. 1	1. 2	1. 4	1. 6	1. 7	1. 9	2. 0	2. 2	2. 3
6	0. 1	0. 2	0. 3	0. 4	0. 5	0. 6	0. 7	0. 8	0. 9	1. 0	1. 1	1. 2	1. 3	1. 5	1. 6
3	0. 1	0. 1	0. 2	0. 2	0. 3	0. 3	0. 4	0. 4	0. 5	0. 5	0. 6	0. 6	0. 7	0. 7	0. 8

In north latitude if the station from which the radio bearing is received lies to the west of ship's position, the correction is additive; if to the east, the correction is subtractive, the mercatorial line of bearing being on the equatorial side of great circle line of bearing. In south latitude the rule is reversed. (The bearings must always be laid off from the radio station.)

67. Ground direction finders.—*a.* Another method of determining bearing and position is by the use of radio direction finder stations on the ground. The direction finder equipment being installed at these stations, no equipment is required in the aircraft except for normal transmitter and receiver. Bearings on the aircraft may be requested and received from these stations. Two or more such bearings when plotted will determine a fix. (For more detailed information refer to the Department of Commerce publication, Commercial and Government Radio Stations, and Hydrographic Office publication No. 205, Radio Aids to Navigation.)

b. The accuracy of radio bearings is dependent upon the radio equipment, personal error, the angle at which the bearings intersect, the path of transmitted signal, which is variable, and further distortion of the path due to objects surrounding the receiving loop and the transmitting antenna. At the present stage of development, bearings and fixes obtained by this method should be considered only approximate.

Section II

RADIO RANGE STATIONS AND THEIR PATTERNS

68. Patterns.—*a.* Begin by comparing a radio range which controls the intensity of its signals in certain directions with a conven-

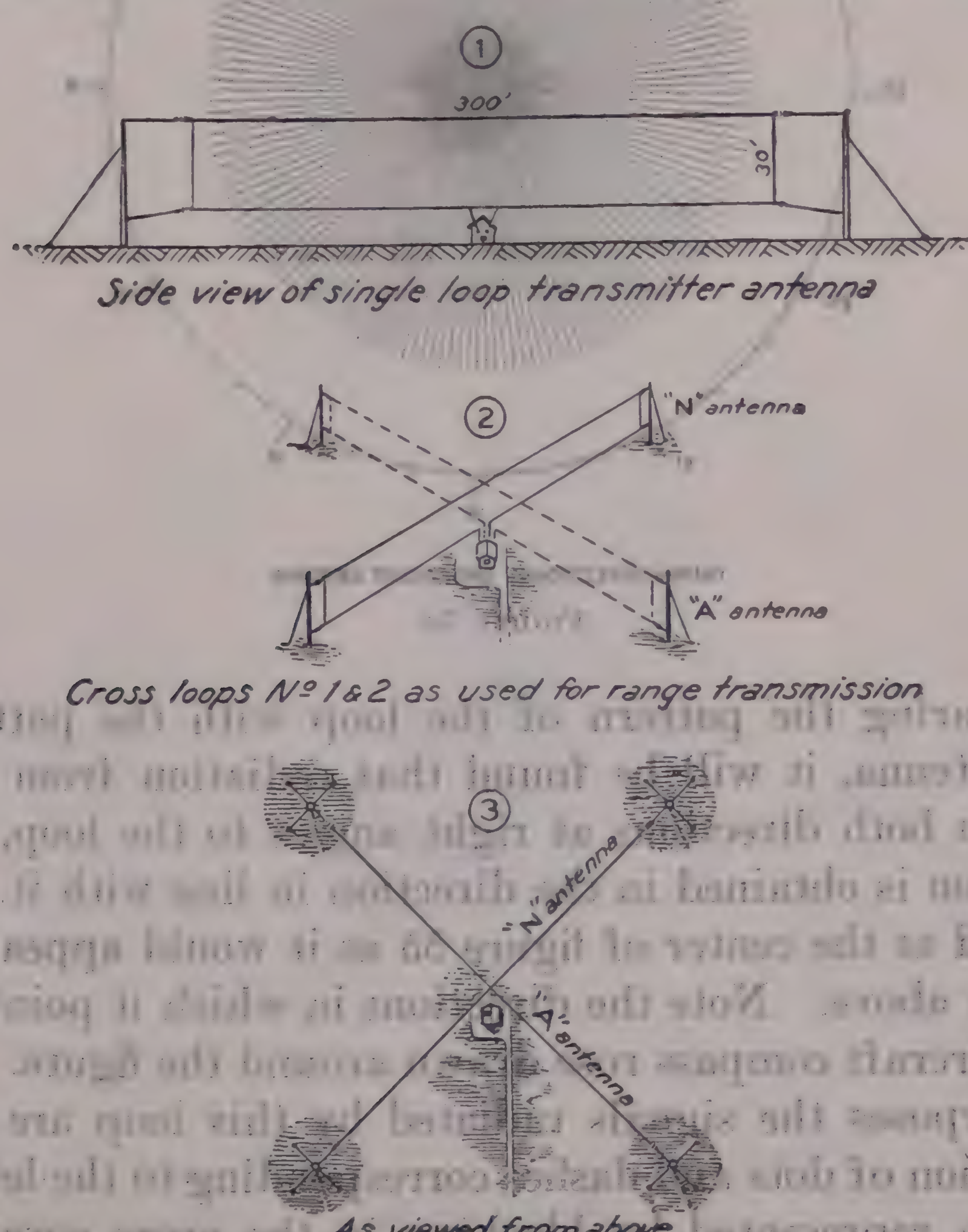
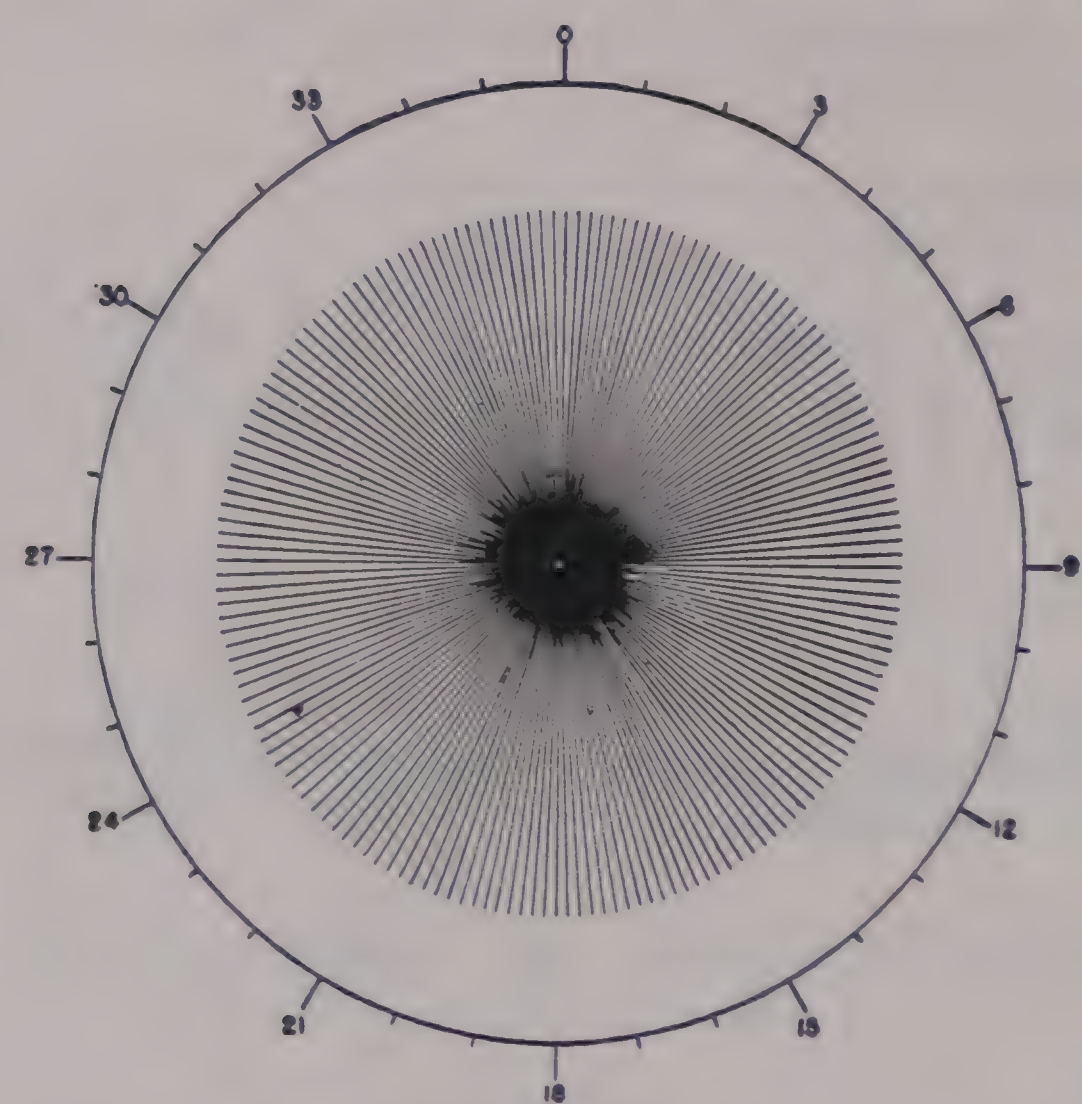


FIGURE 53.

tional broadcast station which normally radiates its energy with substantially the same intensity in every direction. Figure 54 illus-

trates the circular shape of the pattern covering the area over which a broadcast station would be heard with an ordinary receiver. Signals are strong near the transmitter and grow weaker gradually as they spread out in all directions until they fade out entirely. The radius of this circular area could be considered greater or less as the receiver volume is advanced or retarded or the transmitter power is increased or decreased.

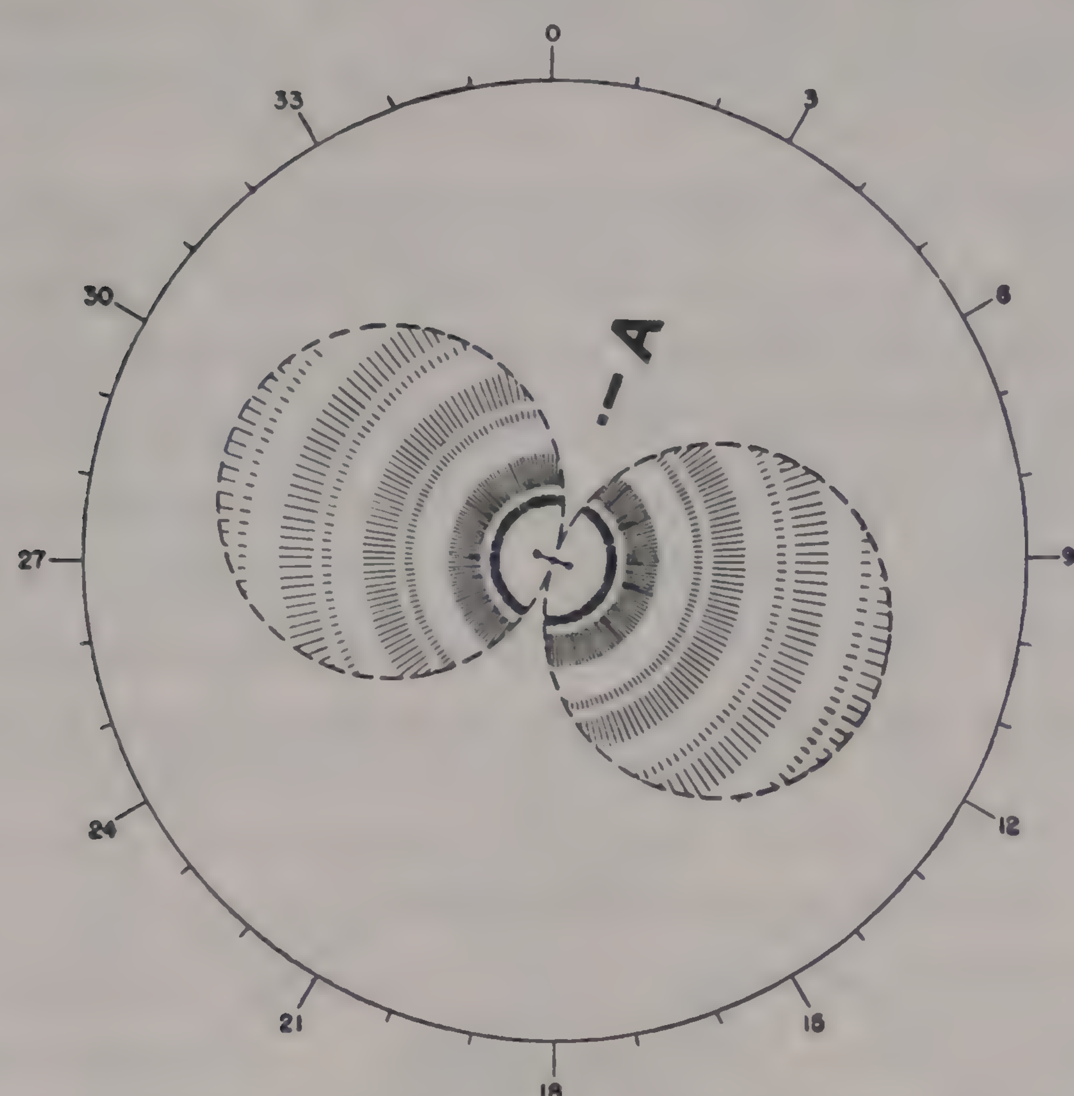
b. The shape of the pattern in which signals are audible can be controlled to some extent by use of specially designed transmitting antennas, one type of which is the loop illustrated in figure 53.



OMNI-DIRECTIONAL BROADCAST ANTENNA
FIGURE 54.

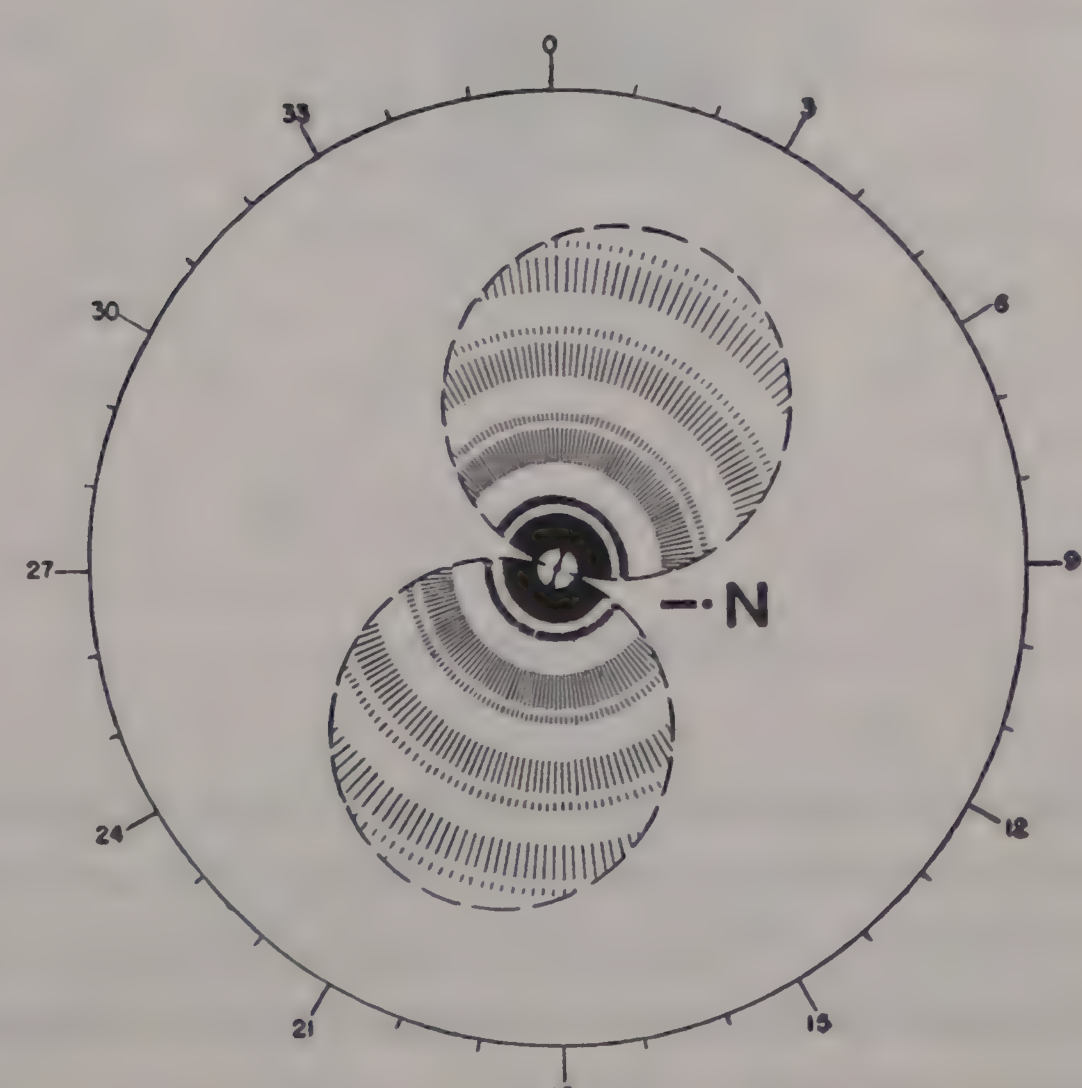
(1) Comparing the pattern of the loop with the pattern of the broadcast antenna, it will be found that radiation from the loop is suppressed in both directions at right angles to the loop, and maximum radiation is obtained in the direction in line with it. The loop is represented at the center of figure 55 as it would appear if viewed from directly above. Note the directions in which it points by reference to the aircraft compass rose drawn around the figure. For identification purposes the signals radiated by this loop are broken up into a succession of dots and dashes corresponding to the letter **A** (dot dash) and so represented by blocking in the areas covered by the signals. Figure 56 represents the area which would be covered by another identical loop at the same location but rotated 90° (at right angles) and transmitting a succession of letter **N**'s (dash dot).

(2) Two such loops radiating alternately would cover the areas shown in figure 57. It is obvious, however, that only in the zones in



SINGLE LOOP
BEARING 100° AND 290°

FIGURE 55.



SINGLE LOOP
BEARING 20° AND 200°

FIGURE 56.

which adjacent areas overlap would both the A and N signals be audible.

(3) At the landing field represented by F in figure 57, both A and N signals would be heard with exactly equal strength, resulting in a steady monotone. The same would be true at any other point on a line drawn through the center of each of the four zones of overlapping signals.

(4) An airplane taking off from the field, flying away from the transmitter and following the line along which the A and N signals continue to be received with equal strength, would start with the receiver volume near minimum. The signal strength would drop off rapidly at first, making it necessary to advance the manual volume control at frequent intervals. (Automatic volume control is unsuitable for range navigation.) As the signal becomes progressively weaker with distance the volume control would have to be advanced less frequently.

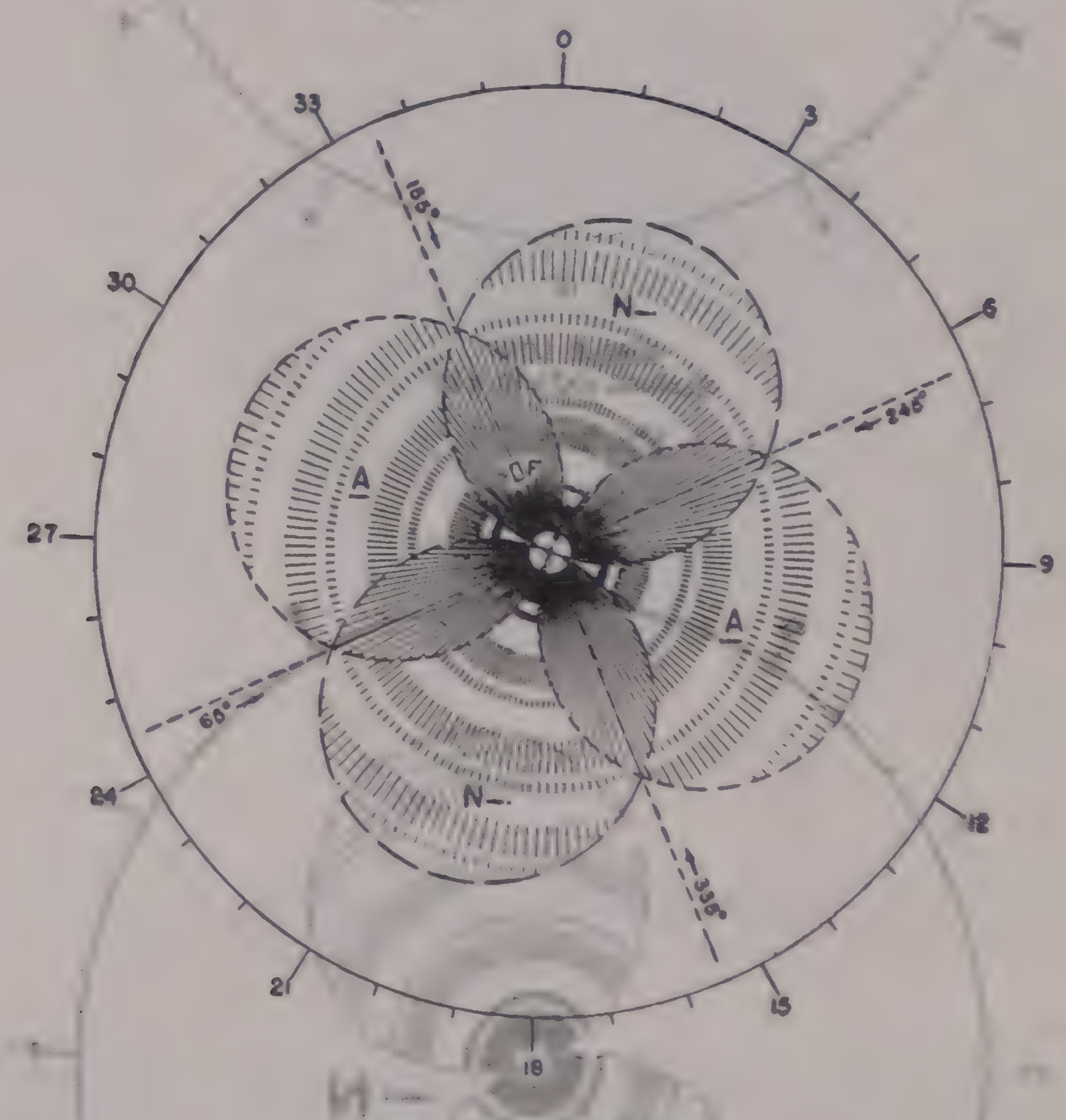


FIGURE 57.

Eventually the limit of receiver sensitivity would be reached or accompanying atmospheric noises and interfering stations become louder than the desired signal. This occurs under ordinary conditions and with normal transmitter powers at from 100 to 200 miles from the station.

(5) At this distance it is possible to fly several miles before a noticeable change in signal strength is apparent to the ear. It is likewise possible to deviate a considerable distance to either side before the ear can detect a change in relative signal strength of the N and A. The limits between which a plane may range to either side before a change in relative strength of the signals is apparent can be represented by a

line radiating from the transmitter approximately 1½° each side of the center line. This is actually the way in which courses are plotted on aeronautical charts. The magnetic bearing of each course in degrees toward the station is published in radio facilities charts for all stations. The use of flying charts on which all courses are plotted with magnetic bearings is explained in detail in Special Publication No. 197 of the Coast and Geodetic Survey.

c. It is now obvious that radio range courses are merely narrow wedge-shaped zones in which two signals of equal strength are received as a monotone. The degree of accuracy with which the ear judges relative signal strength (particularly station identification signals) determines the accuracy with which the pilot can fly a radio range course.

d. Like the entertainment broadcast band, the aeronautical radio frequency spectrum (200–400 kc.) must accommodate a great number of stations, and some interference is unavoidable. To eliminate all danger of mistaken identity, each station is assigned an individual two-letter identification. Approximately every half minute the course signals are interrupted, and the station identification signals are transmitted twice in code, one from each loop, whereupon the course signals are resumed. Each radio range station operates on a designated frequency. This means that only one range station will be received at only one place on the dial. Therefore, there are two means of identifying a radio range station—first, by the radio frequency or dial setting; second, by the identification signals. For instance, the pilot wishes to tune in the radio range at Blank City. He knows that the radio frequency is 260 kc. and that the identification signals are B–U (— . . . . . . —). He turns the radio dial to 260 and receives a signal. He waits until the station identification signals are transmitted and reads them as B–U. This has definitely established the fact that he is listening to the Blank City range.

e. When a pilot is flying away from a range, the farther he progresses the less accurately does he know his position, but if he follows any of the four courses toward the station he will be led to a definite point. That point can be identified aurally by what is usually termed the cone of silence. It is an area normally directly above the transmitting antennas in which all signals fade out when the airplane passes directly through it. It should not be confused with momentary fade-out of signals sometimes found along airways, resulting from other causes, and should be definitely checked by noting whether the zone signal on the right has reversed. Unless the receiver volume

is kept at a minimum value and the airplane is exactly on-course when passing over the station, the signal will not fade out completely. The airplane receiving antenna should be as nearly vertical as possible for best results. The reasons for these precautions will be evident from a study of figure 61, which shows the normal position and shape of the cone of silence. The pilot should have a complete understanding of the inherent limitations of radio ranges before attempting to fly them during inclement weather.

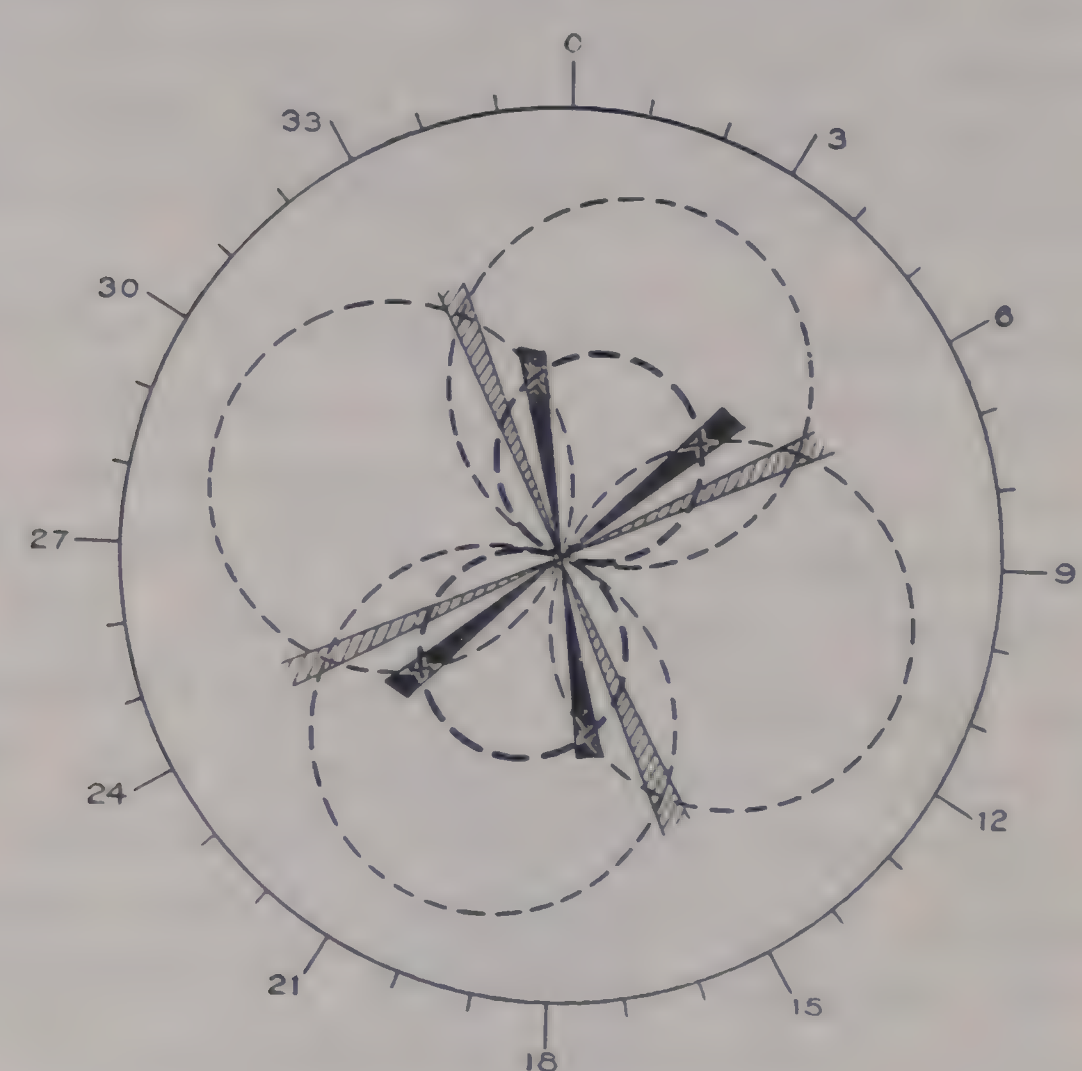


FIGURE 58.

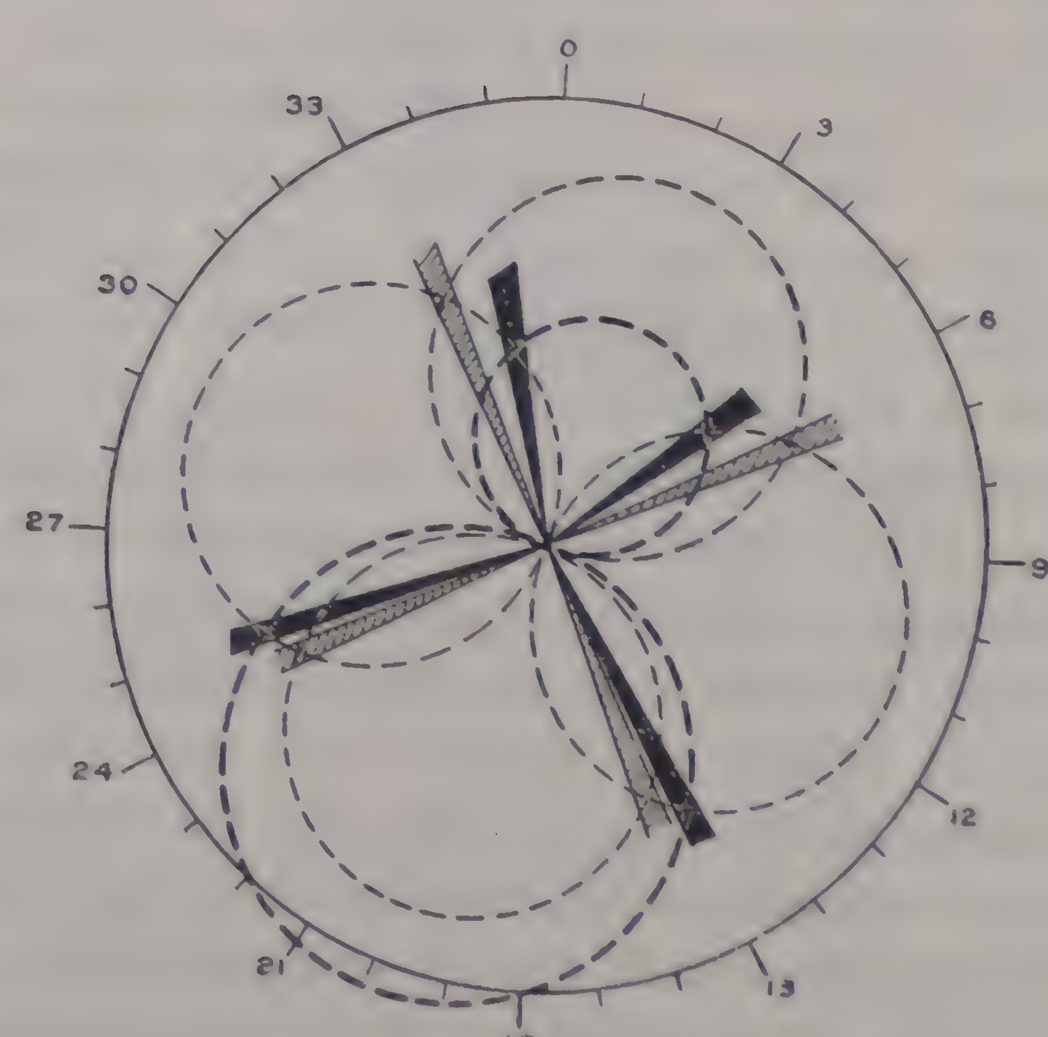


FIGURE 59.

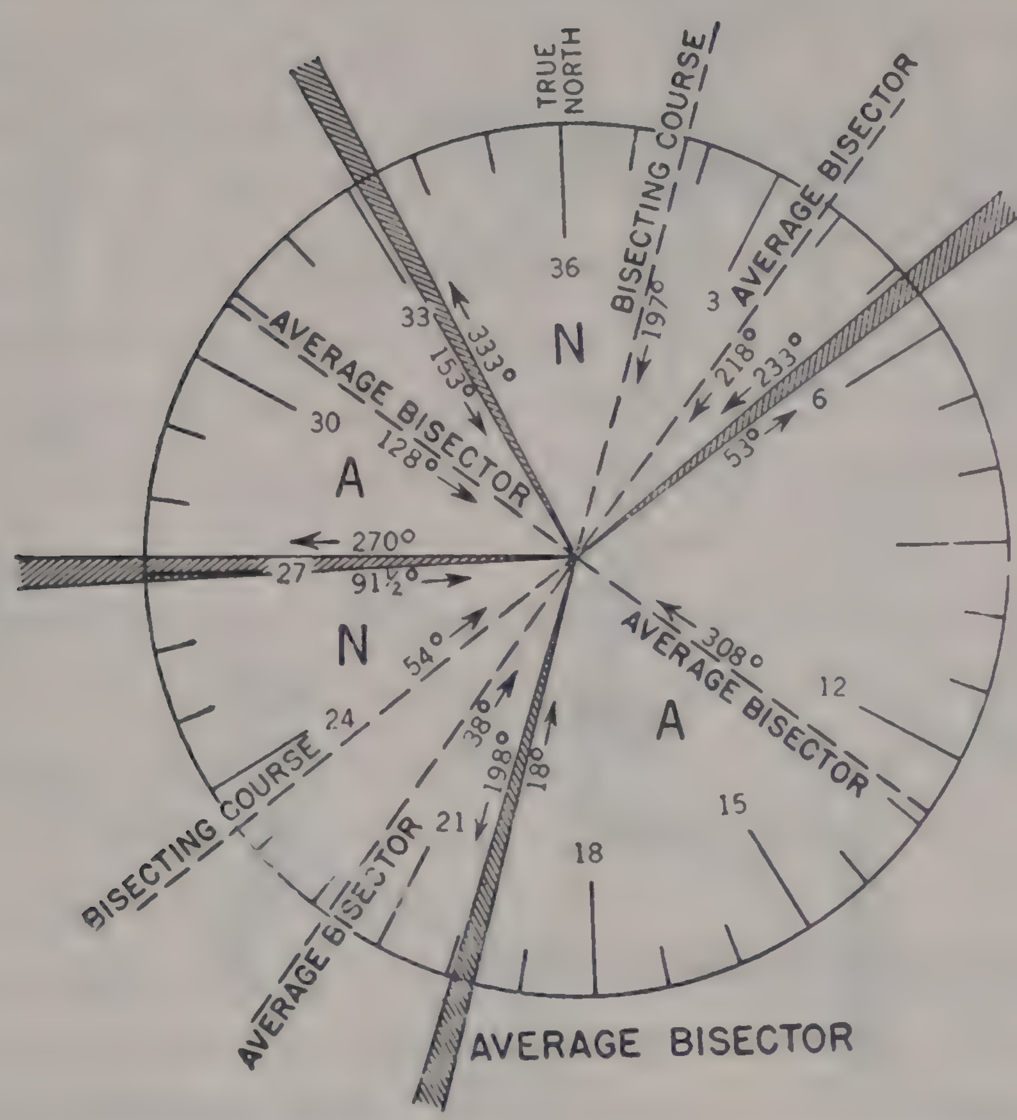


FIGURE 60.

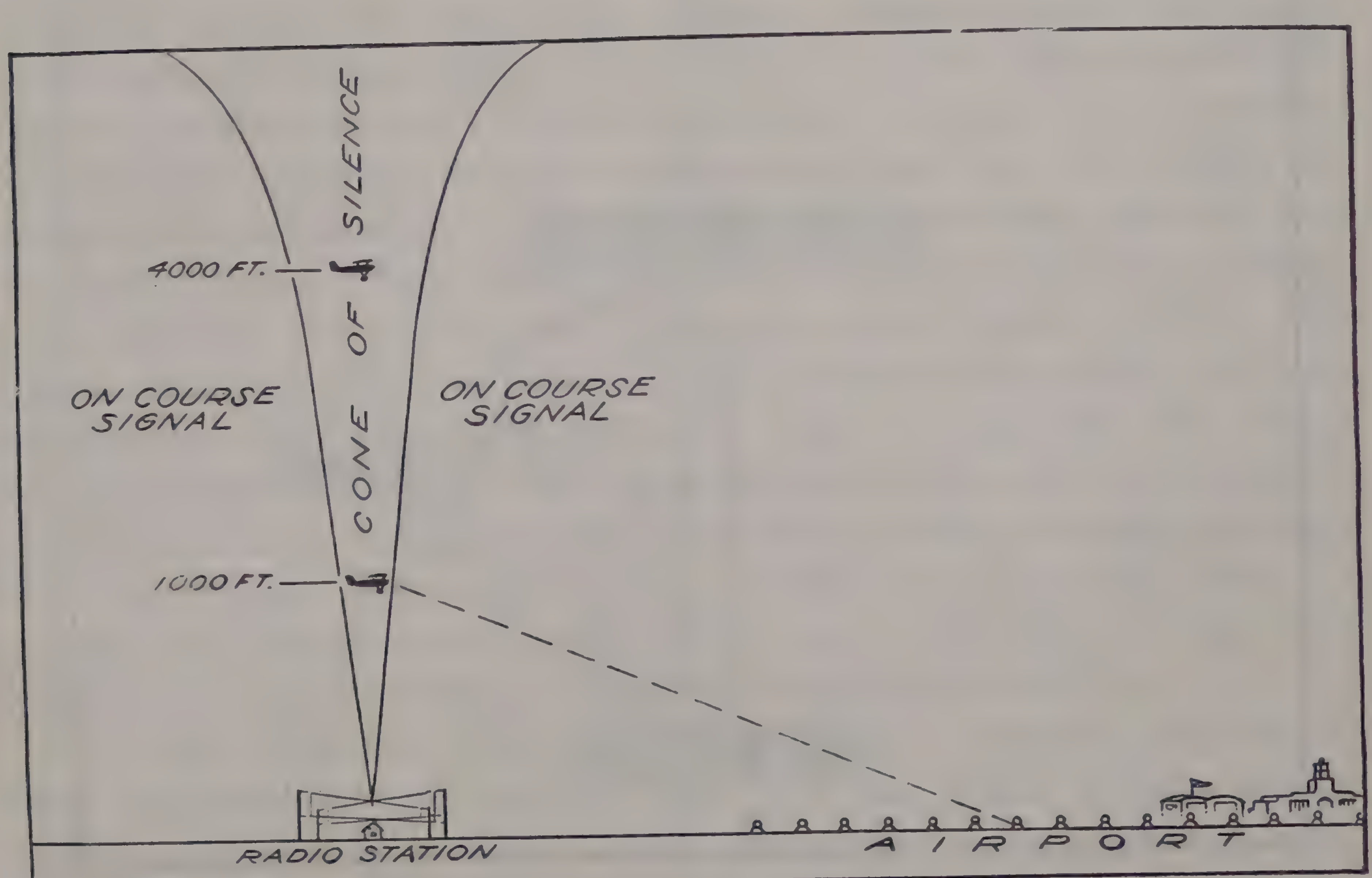


FIGURE 61.

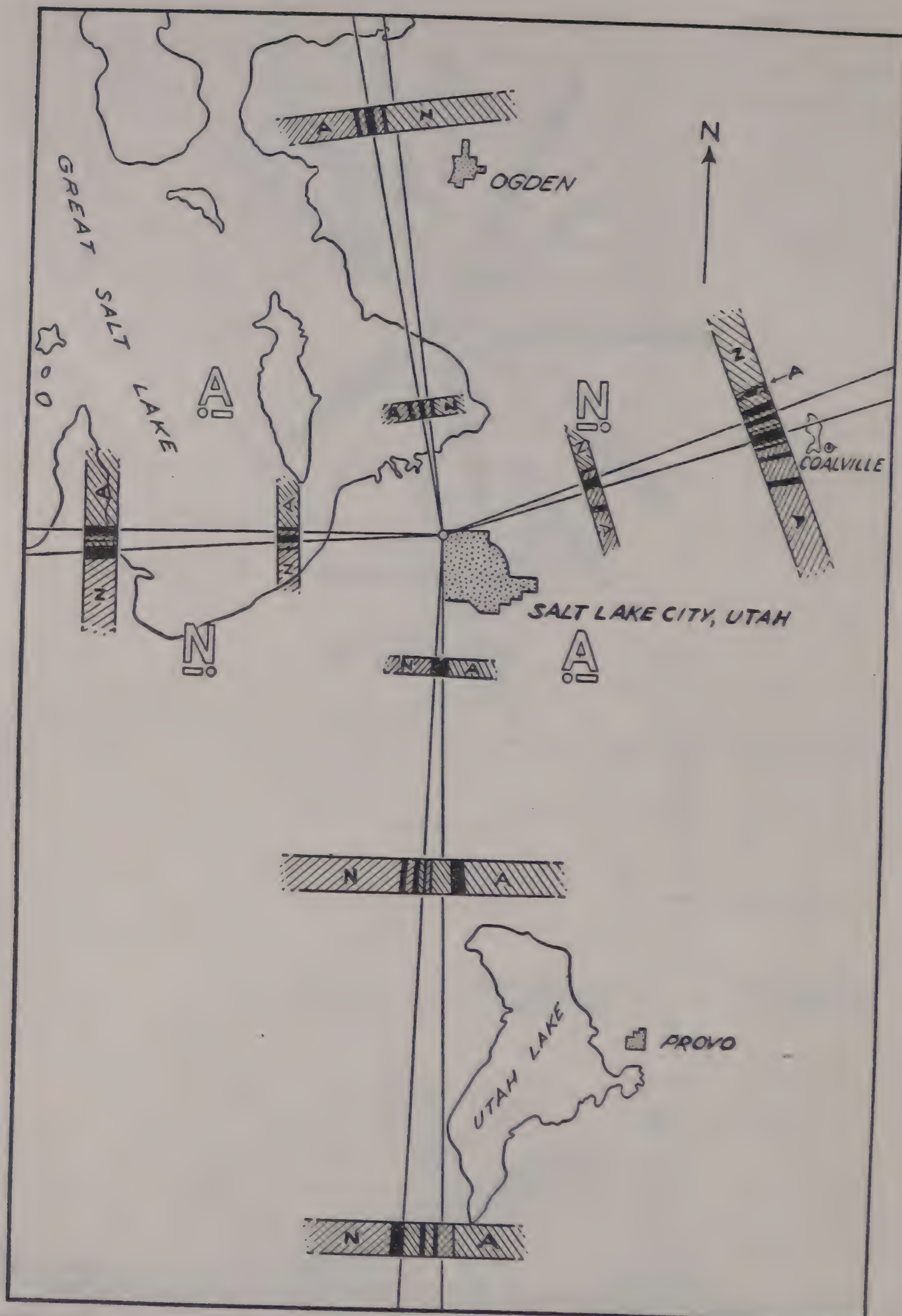


FIGURE 62.—Multiple courses observed on Salt Lake radio range at elevation of 10,000 feet above sea level.

69. Irregularities.—*a. General.*—A radio range beacon in normal operation transmits its signals within a circle with a radius of approximately 100 miles and with the transmitter at the center. The

two characters, N and A, are broadcast. The N is audible in two quadrants of the circle, and the A is heard in the other two. The on-course signal is heard along the lines dividing the quadrants where the pilot hears both A and N at equal signal strength. Along these courses, the A and N merge into a continuous monotone, thus forming what are termed the "radio beams" of the radio range beacons, and the beacon is adjusted so that these beams coincide with routes of the airways which the beacon is designed to serve with directional guidance.

b. Multiple courses.—(1) Where multiple courses exist, they manifest themselves as on-course monotones heard in locations where the predominant signal should be either A or N. They may lead the pilot to believe he is flying on the airway when as a matter of fact he may be some miles from it.

(2) Mountains and rough terrain undoubtedly cause an interference to radio waves resulting in a very uneven distribution in the signal strength producing multiple courses. They exist both with the loop antenna and with the RA type, and there seems to be very little difference as to the number of multiple courses or the area covered. In general, it has been found that within a distance of 10 to 15 miles from the radio range station, the multiple course effect is not sufficient to prevent the use of the range beacon. However, at distances greater than 30 miles from the transmitter there have been many instances of 5 or 6 courses. The spread of these courses, the width of the band, may be many times that of the normal course and in some cases has been known to cover an angle of as much as 18°. The spread or the angle over which these courses exist varies with the distance from the transmitting station. For example, the radio range may have one 3° course, which may extend 10 miles from the station and then at this point may split into 2 or 3 courses covering an angle of 4° or 5°; and again may split at a distance of 30 miles from the station into a band covering 8° to 10°; and at 50 miles, courses may continue to split covering an included angle of 10° to 12°.

(3) There appears to be no continuity to the courses, inasmuch as there appeared to be a band in which courses would appear, but on crossing the course possibly a half mile closer to the station an entirely different arrangement of courses would be noticed. It may also be found that the arrangement of the courses varies widely with altitude. (See fig. 62.)

(4) When a course is directed down a valley which is bound by regularly defined mountain ranges on either side, the splitting of courses is found to be most evident. Courses seem to split up more

under this condition than any other condition which has been experienced. On the other hand, if the courses are projected perpendicular to a range of mountains or several ranges of mountains which are regularly defined, a negligible amount of splitting occurs.

(5) When courses are projected across mountain ranges at an angle, it has been found that they will split at the mountain peak and continue to split, depending upon the number of ranges traversed. In regions where the mountains are irregular, which is generally the case, the results obtained vary widely and cannot be anticipated.

(6) In general, it is believed that the major difficulty occurs in connection with reflections from mountains. This reflected energy either adds to or subtracts from the energy which is propagated in a direct line, depending upon the difference in path lengths and the phase shift at the reflecting surface. Multiple courses are often found to be crooked, while in numerous other cases they are found to be remarkably straight and will lead a pilot directly to the station.

(7) It may also be pointed out that these multiple courses may appear in the following manner: Bounded on both sides by the same characteristic signal; bounded on one side with an A and on the other side with the N as would normally be expected; and the reciprocal of this condition with the A and N on improper sides of the course. In some cases, courses have been found to appear and disappear without continuing into the station from which they emanated, but as a general rule they can safely be used for homing purposes.

c. Bent beams.—Bent courses, sometimes called "dog leg courses," are usually of little consequence since the bend is generally small and away from and around the obstruction that caused it. However, in mountainous country, bends have frequently been found that necessitated a change of compass heading of 45° for a short distance in order to stay on course. Several such bends may occur on a range in a short distance. Obviously such a range would be hazardous to a pilot who was not familiar with that particular range and its peculiarities. These conditions may be found anywhere but are generally confined to hilly or mountainous terrain. A bent course creates the impression that the course is swinging if the airplane proceeds on a straight line.

d. False cones of silence.—(1) Frequent reference is made to so-called false cones of silence, the term being misapplied to what is actually nothing more or less than a "fade." Fading may occur anywhere, but it is generally confined to hilly or mountainous terrain and moderately low altitudes above ground. Occasionally, fading has been noted when flying at low altitude over high voltage transmission

lines. The degree of change in signal strength is not constant, some fades being barely perceptible. Fades in which the signal level drops by as much as a 1 to 10 ratio are unusual except in rugged mountainous terrain. In the Rocky Mountain regions abrupt changes in signal level of as much as 1 to 100 are sometimes encountered.

(2) Usually, these fades are of short duration and seldom require any change in volume control setting. In this connection automatic volume control in any form should not be used when trying to locate the cone of silence, and noise limiting devices, such as a resistor for that purpose in the output stage of the receiver, are undesirable. In some cases the distance over which the fade occurs is relatively long. If the latter is encountered when flying away from the station, especially when within, let us say, 10 miles of the station, the fade is accentuated by the decrease in signal strength due to the increasing distance between the airplane and the station. This often gives rise to such reports as "Distinct fade-out blank miles east." The same fade encountered when flying toward the station may be reported thus, "False cone of silence blank miles east, distinct fade and strong build-up." In the latter case the build-up is more pronounced due to the decreasing distance between the airplane and the station. The closer to the station the fade occurs the more pronounced is the accompanying change in signal strength. In any case the build-up before and after passing through a fade seldom exceeds 2 to 1 so that confusion of a fade with the cone of silence is unlikely.

(3) In conclusion, it may be said that in determining the location of the station it is not necessary to pass exactly through the cone of silence. A reasonable degree of accuracy may be attained by judicious use of the receiver volume control. It will be found that in order to continue listening to the range with any degree of comfort, when approaching the station at the lower altitudes, it is necessary to decrease the volume to practically zero. This applies to any range station. As a matter of fact, locating the station by means of the maximum signal zone (using horizontal type antennas) is just as accurate and effective as by any other method.

e. Night effect swinging beams.—Theoretically, the only time that courses actually do swing from their fixed position is usually for a short period at sunrise and sunset. The reason for this is that during this period the electrically ionized region in the stratosphere, known as the "Kennelly Heaviside Layer," is presumed to be changing its position enough so that the sky wave is reflected back to earth to distort the pattern formed by the field strength of the ground wave, causing the overlap areas to shift positions and the beam swing to

swing. This has been almost entirely overcome by substituting for the loop antenna a system of four steel tower radiators located at the four corners of a large square plot and fed from a transmitter in the center through underground transmission lines. The pilot when flying on a beam of the old type beam station should try to fly the center line of the swings. Near the station this night effect disappears.

f. Misalinement of beams.—The position of the center line should be within 1½° of the published bearing but sometimes it is much farther off than this amount. In a moderate thundershower it was noted that the west course of the Salt Lake range moved northward 13.2°. The other legs shifted from 6° to 11°. The reason for this is the change in the total antenna resistance of the transmitting towers, change of the moisture content of the ground, or a change of the height of the water table under the ground due to the sudden shower. However, a monitoring system is maintained. Not one but several receiving stations are charged with the responsibility of listening to each range for evidence of course deviation or other fault. Any departure from normal is investigated immediately and warnings broadcast to all concerned.

70. Simultaneous ranges.—*a.* Many of the difficulties described are avoided by the use of the five-tower vertical radiator type range stations which broadcast voice and range signals simultaneously. The four corner towers broadcast the N and A signals of the range system, while the center tower broadcasts voice signals. The carrier of the center tower is on at all times, this continuous carrier being of material assistance in radio compass operation; the carrier of the corner towers is on only at those instants when they are putting a dot or a dash on the air; thus while the N signals are being broadcast no carrier is emanating from the A towers and vice versa.

b. With the simultaneous system, the N and A signals are modulated at a 1,020 cycle (audible) tone. Most of the audible portions of the male voice are in the lower end of the frequency band of 200 to 3,000 cycles, with some overtones, harmonic, etc., going considerably higher and some tones lower than this range. There is comparatively little of the human voice right at the 1,020 cycle frequency, so that the elimination of voice frequencies within a narrow range centering at 1,020 cycles has little appreciable effect on speech intelligibilty.

c. To use this system effectively, the airplane receiver circuit must contain a small filter unit. One band of this filter cuts out everything but audio frequencies in the vicinity of 1,020 cycles. In other words, it cuts out all voice signals except the few that happen to be

at this frequency, leaving the range signals undisturbed. The other band cuts out everything in the vicinity of 1,020 cycles, permitting all other frequencies to pass through. In other words, it cuts out the range signals, permitting voice signals to come through to the headset without interference from the range signals. These filters have a three-position switch, permitting either voice signals alone to pass, range signals alone, or both.

d. In operation, the pilot flies with the filter switch set on "both." He hears the range signals, and if a voice broadcast comes on he can usually read either the voice or the range signals without difficulty—just as you can listen to the music or the voice as you desire when someone is speaking on a commercial broadcast with a background of music. If, due to static or some other cause, the voice and range signals interfere, the pilot can, by moving the filter selectors switch to "voice" or to "range," receive whichever signal he elects, alone and without interference from the other.

e. The obvious advantage of this arrangement is to be able to receive all the weather information broadcast and at the same time to have continuous range signals for directional guidance. Another great advantage in static elimination; by putting the filter switch on range, only those signals having an audio frequency of or close to 1,020 cycles come through to the headset, and therefore much of the static as well as the voice interference is eliminated.

f. The filter which accomplishes these most desirable things is quite small and light—about 3 by 4 by 6 inches in size and about 3 pounds in weight.

71. Marker beacons (class M).—*a. General.*—(1) A marker beacon (M) is a low-powered, omnidirective radio station which transmits a characteristic signal, such as H (....) about every 10 seconds. It is also equipped for voice communication with aircraft. Marker beacons have a range of from 3 to 10 miles depending on the weather conditions and the type and condition of receiving equipment being used. Marker beacons are normally placed at the intersection of two radio ranges indicating when to tune to the next station. In such a case the characteristic signals are transmitted on the same frequency as the adjacent ranges so that they can be heard if tuned to either range. Also, marker beacons may be placed on or near some prominent landmark. Usually there is an intermediate landing field located adjacent to the marker beacon, and there are personnel on duty at all times.

(2) A marker beacon does not operate continuously but is turned on when the local ceiling is less than unlimited and the visibility is less than 2 miles or at any time on request. This is because a marker beacon is used by the pilot to check his position when flying with reduced visibility or when flying over the top when the ground cannot be seen.

b. Types.—(1) *Fan markers.*—(*a*) A fan marker is a radio station which transmits upward a fan-shaped pattern which is ordinarily situated crosswise of one leg of a radio range station. These markers are located at definite known distances from the range station, and each transmits a series of dashes which identify the particular marker and leg, thus providing the pilot with a definite fix. These markers are also used as outer and inner markers in various instrument landing systems.

(*b*) The selection of dashes follows an arrangement by which the fan marker on the true north leg of a radio range station or, where there is not true north leg, on the first leg clockwise from true north, is assigned the characteristic signal of one dash. Fan markers on other legs of this range will have 2, 3, and 4 dash groups in their respective clockwise order. With this arrangement, coinciding legs of two radio range stations will always have differently keyed fan markers, and the keying arrangement will give a definite indication to the pilot as to which leg of the range he is on. (See fig. 63.)

(2) Z-*markers.*—(*a*) Z-markers, which are being installed at radio range stations as a supplement to the cone of silence and which operate on the same frequency as the fan markers, will not be keyed. They will have a steady signal to differentiate them from fan markers. All markers will be received on a pretuned marker receiver. The characteristic tone of each as heard in the pilot's headphone will also be alike (3,000 cycles), the only difference being in the keying. They operate on a frequency of 75 megacycles with 3,000 cycle audio frequency.

(b) The pilot in flying the regular range signal hears the marker signal superimposed on the range signal as the ship passes over the range station. It becomes audible slightly before the ship passes into the usual cone of silence and increases rapidly to a predetermined

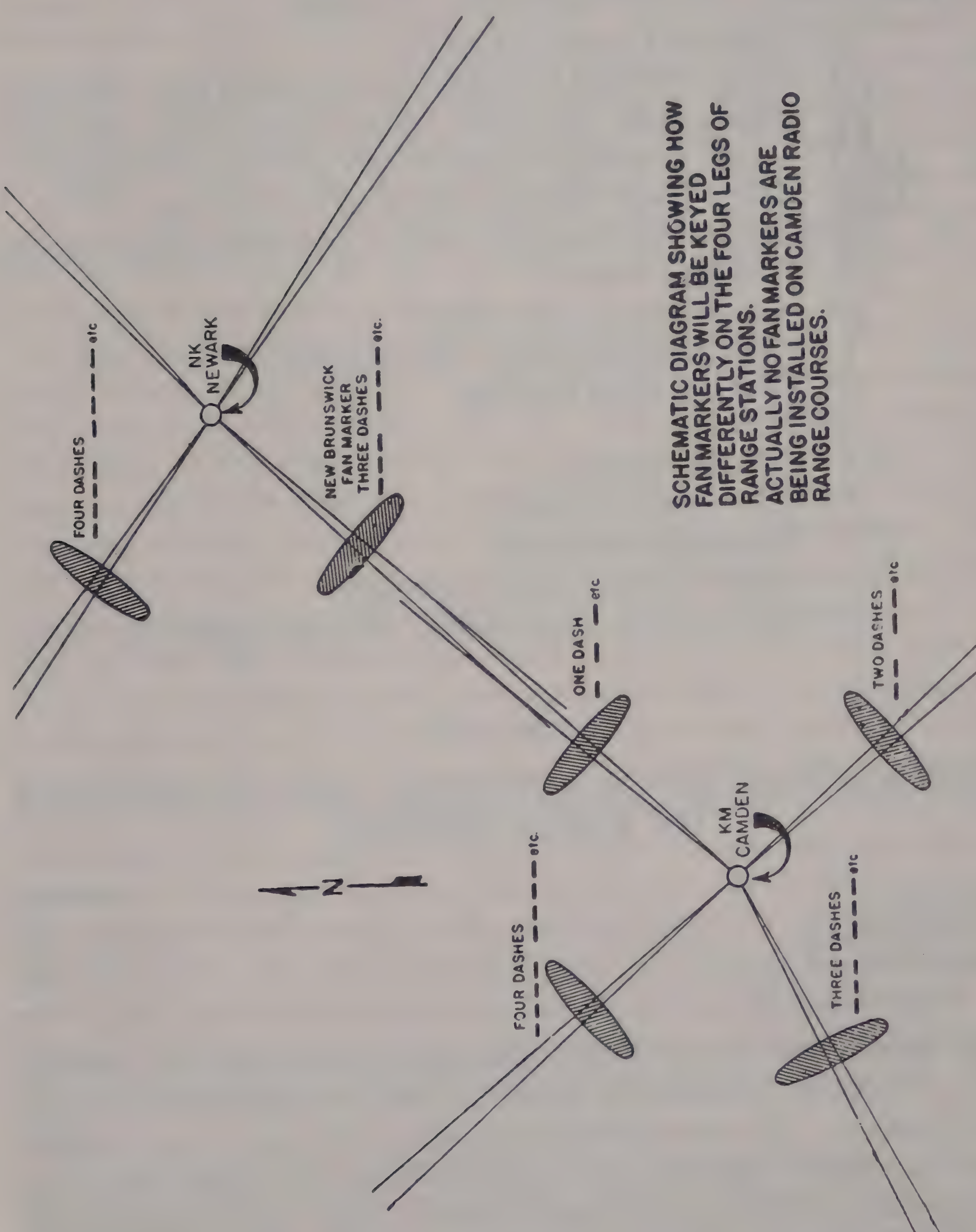


FIGURE 63.

maximum loudness. The maximum loudness signal remains constant for a considerable period, depending upon speed and altitude, and then fades away. Being of high pitch, the marker signal causes no interference in reception of range signals.

(*c*) The visual signal is a standard 12 volt switchboard lamp mounted on the instrument panel adjacent to the flight instruments. It remains lighted over most of the period that the marker signal is audible.

c. Designations used to denote class of station.

B—Scheduled broadcast station.
RA—Range (vertical radiators) power greater than 150 watts.
RL—Range (loop radiators) power greater than 150 watts.
MRA—Range (vertical radiators) power 50 to 150 watts.
MRL—Range (loop raditors) power 50 to 150 watts.
ML—Directive or loop type marker, power less than 50 watts.
FM—Fan-type marker.
M—Nondirective radio marker.
V—Voice communication with aircraft.
W—Without voice facilities.
T—Teletype.
TX—Principal teletype.
P—Point-to-point radio.
D—Distantly controlled.
Z—Range station location marker.
S—Simultaneous transmission of range signals and voice.

Section III

AIRCRAFT RECEIVER ANTENNAS AND THEIR EFFECT ON RANGE SIGNALS

72. Radio beam.—*a.* Before considering the effect of different types of receiver antennas, it would be well to review briefly what a radio beam is. As was described previously, the beam or on-course is merely a rather indefinite path along which the pilot hears two different sets of signals with equal volume so that they interlock and sound like one signal. Any phenomenon which increases the volume or strength of one of these signals, or anything which decreases the strength of one of them, makes it necessary for the pilot to fly off to one side to find the line along which the signals again sound equal. There are various causes for such effects as was explained under bent and multiple courses.

b. Suppose, for example, that a beam lies across a large airport and we taxi out onto this field with a plane equipped with a radio receiver; we turn on the receiver and find that in the middle of the field we hear a solid on-course signal. Say the station is south of us and we are at the moment headed toward it. Off to our left is the A zone and to our right the N zone. Now, suppose that over to our right in the N zone a rain shower or any imaginable cause has changed the reflective or absorptive quality of the ground, and the signal strength of the N zone is decreased. The N would then not be quite so loud as the A, and we should no longer hear a solid on-course but would be able to detect a slight A off-course signal. But by taxying over to the left hand side (east) of the field we would again hear a solid on-course.

c. Assume that conditions are again back to normal and we are again sitting in the airplane in the middle of the field hearing a solid on-course. (Remember that the signal strength is greater in the middle of the zones than it is where the on-courses lay.) Suppose we turn the airplane, which is equipped with an inverted L-shaped antenna, so we are headed crossways to the beam. The L-shaped antenna is directional; that is, it will pick up signals with greater strength from the direction one end is pointed than it will signals from the direction the other end is pointed. We now are sitting on the field with the airplane across the beam and one end of the antenna is pointed toward the A zone and the other toward the N zone. Bearing in mind that the antenna picks up signals stronger from one end than it does from the other, it follows naturally that the N signals are slightly louder in the receiver than the A signals. Consequently, we hear a slightly off-course signal even though we are still sitting in the same spot and did nothing but turn the plane 90°. We then turn the plane 180° so we are still headed across the beam but in the opposite direction. The directional antenna is now picking up the A slightly stronger than the N, and we hear in the receivers a slightly off-course signal on the A side of the beam.

d. Suppose we taxi across the field until we again hear a solid on-course signal and then turn south (toward where we know the station is located). When we get headed south we find that instead of the on-course signal, we now have (since we turned) a slight off-course signal, therefore, we turn again and taxi across the field to where we hear an on-course signal again; but when we again turn toward the station we again hear another off-course signal on the other side of the beam. Due to undesirable directional effect of the

antenna, the beam apparently swings every time we turn the airplane. Obviously, it is impossible accurately to follow a beam in actual flight under such conditions. It naturally follows, then, that for radio range flying the receiving antenna on an airplane should be as nearly nondirectional as possible.

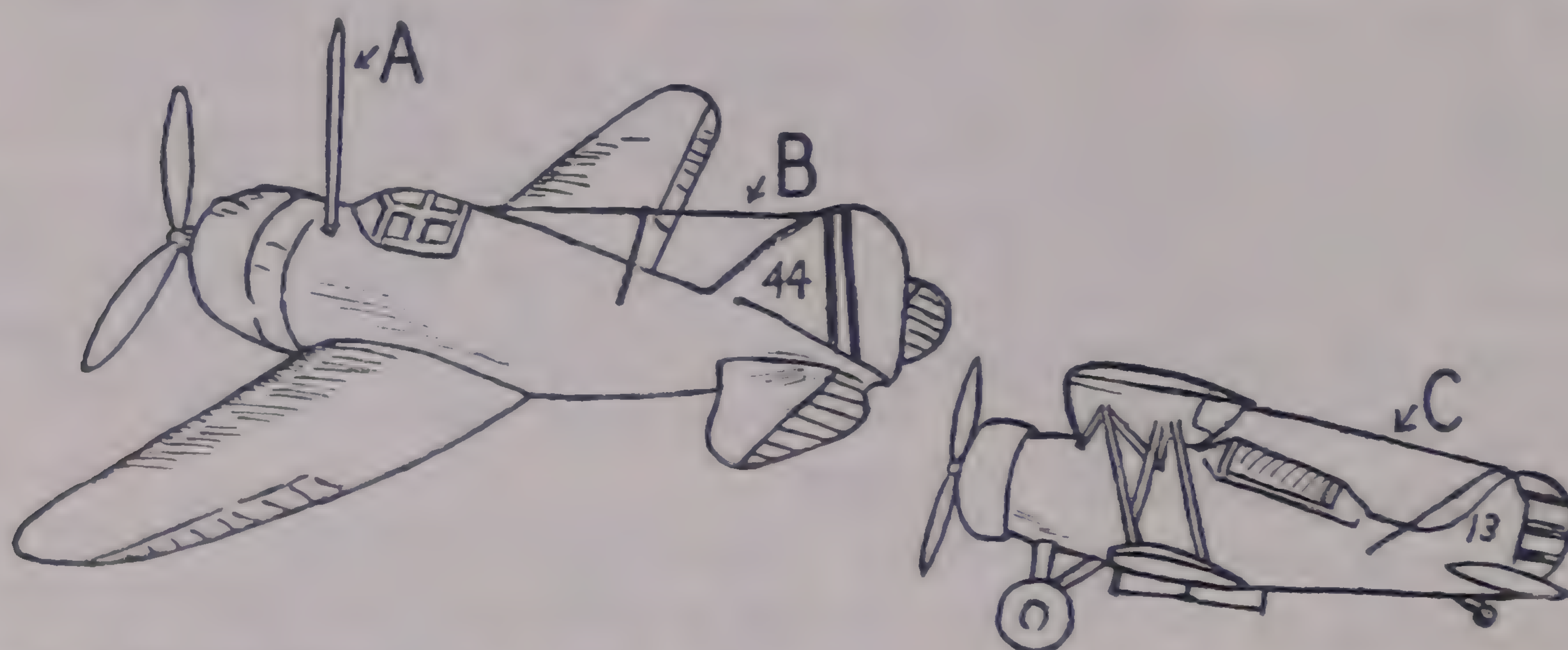


FIGURE 64.—Airplane antennas: mast type (A); T-type (B); inverted L-type (C).

73. Types of antennas.—*a*. Three types of antennas have been proven to possess excellent beam riding qualities. These are as illustrated in figure 64 and as described below:

(1) The mast antenna is simply a vertical conductor inside a wood or metal streamlined support. Having no horizontal component, it is strictly nondirectional.

(2) The flat top (T-type) is usually run from a small mast on the top of the wing to a point on the vertical stabilizer, when mounted on top of the airplane. When mounted below, it is usually run between two stub masts projecting down from the bottom of the fuselage. This latter installation has the advantage of the antenna not being shielded by the engine and other parts of the airplane, especially when nearing the station, but its use is limited to such airplanes as have sufficient clearance between the fuselage and the ground when at rest. While this type of antenna is directional, in that it is most effective over its ends, it does not distort range signals because the directional effect of one end is equal to and cancels the directional effect of the other end. The lead-in must be electrically centered in the flat top and extend downward or upward vertically to the receiver.

(3) The whip antenna is frequently used on the larger types of aircraft and is usually mounted under the nose of the ship, pointed downward. It is a semiflexible rod or tube and when the ship is at rest is straight. In flight it bends back slightly, having no additional support as does the conductor in the mast antenna.

This type has only a small horizontal component and so is very nearly nondirectional.

b. (1) The lead-in, regardless of the type of antenna, is one of the most important parts of a radio installation, as without the correct installation of this unit good results in range flying and cone intersection cannot be achieved.

(2) The lead-in has a highly directional effect which in a correct installation can be used to advantage. For best results it must be vertical when the ship is in flying position and lead directly to the receiver. If the receiver cannot be located directly under the lead-in, the lead-in should be brought down vertically as far as is practical, or level with the receiver, and the remainder to the receiver, thoroughly shielded. The location of the receiver should be selected so that the amount of shielded antenna can be kept at a minimum, as several feet of it will somewhat reduce the effective range of the receiver.

(3) It is a common occurrence to hear a pilot state that while riding the beam in clear weather he got the cone several miles to one side of the station. Inquiry will invariably show that he was flying a plane with an antenna running from a wing tip to the tail, and that the lead-in came from about the middle of the antenna diagonally down to the fuselage. Lead-ins which "lean" fore or aft will also produce the effect of a leaning cone of silence, but they will cause a cone to be received well before or well after passing over the station, depending on which way the lead-in leans.

(4) For accurate results the lead-in must be vertical.

74. Automatic volume control.—The purpose of automatic volume control (AVC) is to attempt to take all incoming signals, regardless of their strength, and put them into the earphones or loud speaker at the same volume. The use of automatic volume control on radio range signals would, therefore, defeat the purpose of a radio range. Suppose a pilot is flying off-course along the bisignal zone and getting an A which is about twice as loud as the background "buzz" from the other quadrant. If he switches his radio to automatic volume control, that feature in the receiver attempts to decrease the volume of the loud A and increase the weak N and tries to put them into the earphones at the same level. Thus automatic volume control attempts to give the pilot an on-course signal whether he is on-course or not. The result is to do two things: first, apparently to widen out the beam and render it very indefinite as a path to follow; and, second, to make it nearly im-

possible for the pilot to recognize whether the signal is fading or building. The radio should, therefore, always be set to manual control of volume and not automatic volume control when working radio range problems.

75. Use of volume control (blocking).—For best results in radio range flying it is necessary to maintain the volume at a comfortably low level. In working problems involving the detection of a fade or build in signal strength it is, of course, necessary to carry the audio volume as low as is possible and still read the signals. At all other times the volume should be carried as low as can be comfortably and clearly understood. There are two reasons for this: one, it is difficult to get a cone of silence or, if the cone is missed, recognize that the station has been passed if the volume is high; two, there is the danger of the receiver "blocking." Different radio men will have different explanations and terms to explain blocking. The instrument pilot and instrument instructor are chiefly concerned with the fact that it occurs and what will prevent it. If the volume is carried too high and the signals allowed to blast in, it is possible to get an apparent reversing of signals. As the pilot is nearing the station and is intent on his corrections to stay on-course, he forgets, say, to keep the volume down to the proper low level. At this point if he runs off-course the quadrant letter will come in clear and loud. If this off-course signal becomes loud enough it will block or momentarily paralyze the tubes and come through the headphones as a whisper. Meanwhile, the other quadrant letter, coming through the set at a normal level, is clear and distinct. Consequently, if the pilot is in an N when this occurs, the N will be soft and the A relatively loud, and the pilot will be led to believe that he is in the A sector on the other side of the beam from where he actually is.

CHAPTER 5

WEATHER DATA; OPERATION AND PROGRESS RECORDS

76. Weather data.—*a.* Weather data should be injected into problems after the different systems of orientation have been taught and problems such as "let-downs" started.

b. Weather broadcasts should be given at points that will tend to confuse a pilot who does not have the situation well in hand. However, in the use of these broadcasts, be careful not to inject them into problems before the student has a fair understanding of orientation. Be sure that the simulated conditions correspond with conditions that actually can and do exist. For the ordinary problem, weather broadcasts may be put out at the proper times for the particular range being used, or special weather reports may be used, pertaining to winds aloft, made up to suit the situation.

c. Weather sequences prepared for the student's information in formulating a flight plan for cross country problems may be made up to present many different problems that will have to be taken into consideration. In addition to weather data furnished the student before the flight, changes may be effected and broadcast to require him to make changes during the problem. These changes may take the form of storm or icing conditions arising at point of destination or in the line of flight to destination. Instructions to change altitude, etc., should be broadcast to "other" ships in the vicinity. Here again the possibilities for different situations are limited only by the imagination of the desk operator. Make the weather conditions and any changes to them feasible. All meteorological data used in problems should be prepared and given in the manner and sequence as laid down in Air Corps Circular 105-2. Particular attention should be given to wind direction and velocity in giving weather reports, as any simulated wind must be allowed for in the automatic recorder if it is given on a weather broadcast.

253530°—40——8

77. Daily operation record.—(See form below.)—A separate sheet is kept for each trainer being used. The name and grade of individuals flying the trainer, the type of work or problems that they perform, their progress on the last exercise, and the time taken to perform them are entered in the proper columns. Total time of the individual's work is transcribed to the student's individual progress record while the total time of the trainer is entered on W. D., A. C. Form No. 47 at the end of the working day. This record is self-explanatory and should be faithfully followed and kept up. The usual procedure is to retain all forms for 6 months in a file that is easily accessible for reference. At the end of the 6 months the forms may be filed or destroyed at the discretion of the officer in charge.

LINK TRAINER DAILY OPERATION RECORD

Form ----------
Trainer type --------------
Trainer No. --------------

Date ------------
Organization ------------
Station ----------------

Name and grade	Time	Exercise	Grade	Remarks	Posted (initials)	Instructor

Total time ---------------- Instrument trainer officer -----------------

(Front)

INSTRUCTIONS

Each lesson conducted in the trainer will be entered, supplying the time in the trainer in minutes under "Time"; the number of the exercise or problem, as listed below, under "Exercise"; and A, B, or C, in accordance with the following, under "Grade":

A—If pilot remained within tolerance limits given in the instructor's guide for the particular exercise.

B—If student only occasionally slightly exceeded the specified limits.

C—If the pilot definitely needs more practice on the exercise in question as indicated by repeatedly exceeding tolerance limits.

Under "Remarks" note particular difficulties encountered by pilot. Under "Posted" insert instructor's initials when data have been posted to the individual progress record.

Each entry will be signed by the instructor.

Exercise number:

1 ---------- Familiarization.
2 ---------- Straight course.
3 ---------- Straight flight.
4 ---------- Standard rate turns.
5 ---------- Turns to predetermined headings.
6 ---------- Coordination of throttle and elevators.
7 ---------- Straight climbs and glides.
8 ---------- Climbing and gliding turns.
9 ---------- Climbing and gliding turns to predetermined altitudes and headings.
10 ---------- Repeat numbers 6, 7, 8, and 9 with rough air.
11 ---------- Repeat numbers 8 and 9 with rough air.
12 ---------- 30°, 10°, 5°, and 2° turns to gyro headings.
13 ---------- Use of artificial horizon.
14 ---------- Emergency pull-up.
15 ---------- Stalls (without spinning).
16 ---------- Spins.
17 ---------- U-track.

Radio:

R1 ---------- Signal familiarization.
R2 ---------- Beam interception and bracketing (mechanical).
R3 ---------- Beam interception and bracketing (advanced).
R4 ---------- 90° system of orientation.
R5 ---------- Existing marker beacon uses.
R6 ---------- True fade-out system of orientation.
R7 ---------- Parallel system of orientation.
R8 ---------- Fade-out 90° combination of orientation.
R9 ---------- Parallel-perpendicular system of orientation.
R10 ---------- Lost on beam system of orientation.
R11 ---------- Multistation system of orientation.
R12 ---------- Unknown station system of orientation.
R13 ---------- Close-in procedure.
R14 ---------- Radio compass(homing).
R15 ---------- Radio compass (position finding).
R16 ---------- Let-down procedure and how to approach.
R17 ---------- Instrument landings.
R18 ---------- X country.

(Back)

78. Individual progress record.—The form following is as its name implies the student's record of progress in the course and is used as a record of problems performed by the individuals taking refresher time. The primary purpose is to furnish the instructor with a complete record of the student's progress and time used in the various

phases of the instruction. One form will be kept for each student. The date he receives training will be entered in the column pertaining to the phase and date, also his progress on the last exercise. The form will be retained indefinitely in file by the instructor.

INDIVIDUAL PROGRESS RECORD

Form--------

Name and grade------------------------------

Organization-------------------- Station-------------------

Date	Time	Exercise	Grade	Trainer No.	Instructor	Remarks

Total time----------- Instrument time----------

Radio time---------- Instrument trainer officer----------------------

79. Charts.—*a.* Due to the fact that radio facilities are constantly changing, it is not possible to prepare charts for use in orientation, let-downs, and navigation problems for all stations that may be used indefinitely.

b. Charts should be compiled from existing data of various ranges and should be discarded as soon as any change in the real range is made.

c. Ranges selected for duplication should be representative of the various types, i. e., square, scissor, and crow foot. In addition, a range subject to various peculiarities, such as bent beams, multiples, etc., should be selected.

d. For navigation problems any section of the country may be selected. However, the selection should include several beams and a portion or portions of the civil airways.

e. Charts to be used in let-down problems are made of stations and the surrounding area of stations that are busy civil terminals such as Chicago or Newark. These charts should include obstructions and minimum safe altitudes as well as the normal data.

f. The charts must be drawn to scale with the airport and obstructions properly situated.

g. It is necessary for the beams at the transmitter and for some distance out to be very narrow in order to reproduce correctly the same conditions as experienced in actual flight. A fine line to indicate the beam width for 1 inch from the station is sufficient.

h. Landing fields and obstructions may be represented by approximate outlines not necessarily to scale.

i. Make allowance on some unused portion of the chart for data concerning date, pilot, and time of problem.

j. Cross-country charts may be made up in any size and to any scale. However, the scale of standard sectional for long problems is very good. This gives an airspeed of 420 m. p. h. in working problems of this type which serves to speed up the problem and consequently the student's mental processes.

k. In preparing charts of this type, sectional charts may be used as a reference; in fact by the use of tracing paper or cloth, the outline of populated areas, airport location, seacoasts, etc., may be transferred accurately and then the radio beams of the various stations blocked in.

l. Blue prints or multilithed copies may be used.

INDEX

[A. G. 062.11 (7–2–40).]

BY ORDER OF THE SECRETARY OF WAR:

G. C. MARSHALL,
Chief of Staff.

OFFICIAL:

E. S. ADAMS,
Major General,
The Adjutant General.

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